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(Continuing the Journal of the Allied Dental Societies)

A journal of stomatology; devoted to the advancement and dissemination of knowledge pertaining to the mouth and teeth, and to their relations to the body as a whole

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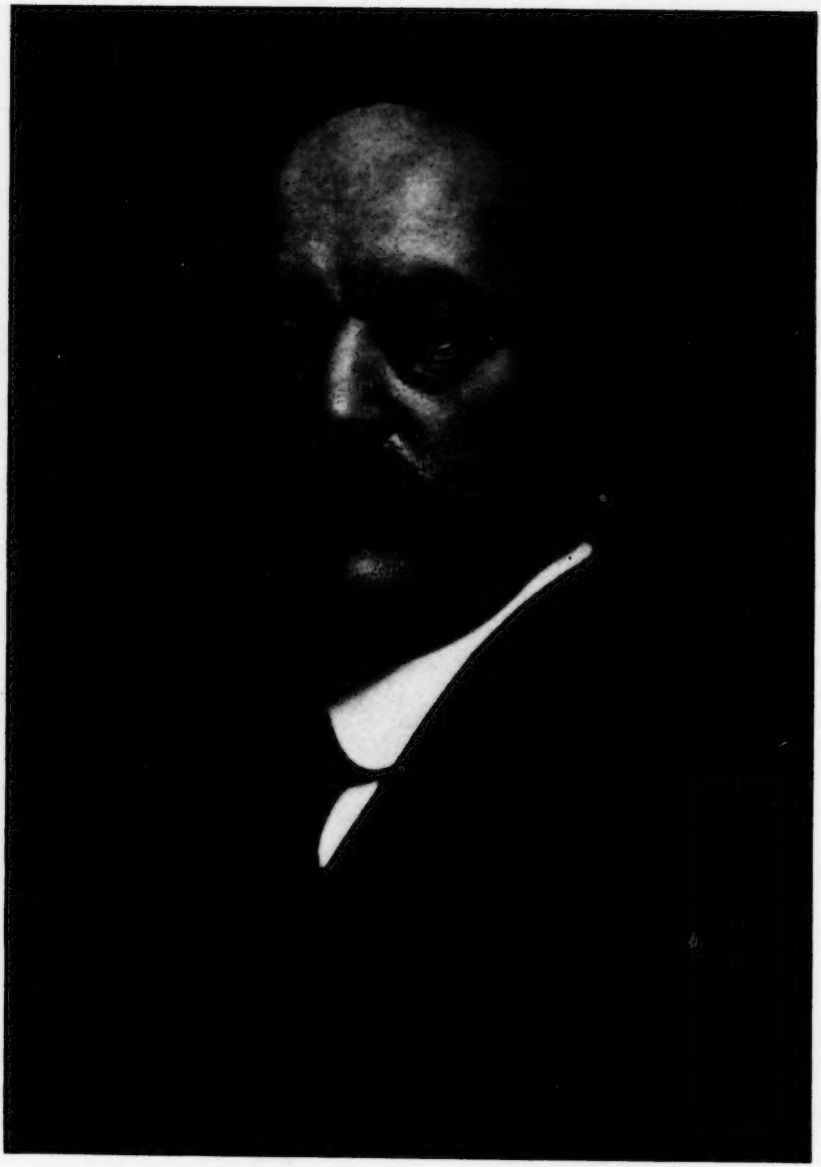

Samuel J. Meltzer

In Memoriam

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Died

November 7, 1920, in New York City

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Ex-president of the American Gastro-Enterological Society

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Ex-president of the American Physiological Society

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Devoted to the welfare of the country of his adoption

Universally respected and esteemed

A continuing inspiration to his colleagues in medicine and science the world over

An abiding constructive influence in the advancement of civilization

A MICROSCOPIC STUDY OF PULPS FROM INFECTED TEETH

ARTHUR T. HENRICI AND THOMAS B. HARTZELL[1]

Department of Bacteriology and Immunology, University of Minnesota, Minneapolis, Minnesota

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II. Histological observations 538
Descriptions of the vital teeth, with statements of the corresponding findings 539
III. Discussion of the findings 547
IV. General conclusion 549
V. Literature cited 550

I. INTRODUCTION

It is generally considered that so long as the pulp is protected by an intact wall of dentin, it is free from infection; that only when the pulp chamber becomes exposed by caries or trauma does the pulp tissue become invaded by microörganisms, and that then it usually undergoes suppuration or gangrenous inflammation; and that the pain which occurs previous to actual exposure of the pulp is due to hyperemia, caused either by temperature changes or by lactic acid absorbed through the dentinal tubules. This conception of the process of natural devitalization finds general expression in the text-books on dental pathology.

We believe, on the contrary, that the pulp is frequently invaded by microörganisms long before it has been exposed by caries or, indeed, in the absence of caries, by organisms which have passed into the pulp from the gingival region; and that such invading organisms give rise in the pulp to localized areas of inflammation which are not necessarily suppurative or gangrenous in nature, but rather granulomatous and progressive, leading to fibrosis or other changes. When suppuration and gangrene finally occur, it is in a tissue which has

[1] Aided by a grant from the Research Commission of the National Dental Association.

long been subjected to injury by milder types of infection, and suppuration is here merely the final stage of the process.

The idea that the pulp is sterile until actually exposed by caries is based on a false conception of caries itself, which, however, is still generally taught, namely, that caries is caused by a variety of saprophytic, acid-producing, bacteria and that lactic acid, and a resultant softening, precede bacteria in the invaded dentin. But, as we have pointed out previously, it has long since been demonstrated by Goadby, Kantorowicz, and Niedergesäss (each working independently), that streptococci may be demonstrated, in the dentin, well in advance of any softening; and that, as a matter of fact, saprophytic bacteria and lactic acid are merely the camp-followers of an invading army of pathogenic cocci. It is, therefore, not surprising that the presence of organisms may be demonstrated in the dental pulp long before the softening of the dentin has extended as far as the pulp chamber. In a previous paper (1) we presented the results of bacteriological studies, which indicate that in nearly one-half the number of cases where teeth or their investing tissues are infected, bacteria, of which non-hemolytic streptococci are the predominant species, are already present in the pulp tissues. In concluding that paper we stated that the presence of these bacteria in the pulp "must be accompanied by some chronic inflammatory changes in the tissues." In the work here reported we have made a histological study of a similar series of pulps, and have succeeded in demonstrating the occurrence of the chronic inflammatory reactions which we predicted.

II. HISTOLOGICAL OBSERVATIONS

A series of fifty *vital* teeth, taken as they came from the clinic, were used in this study. They were cracked open with bone-cutting forceps, and dropped into Zenker's solution. After the pulps had been sufficiently hardened, they were carefully stripped out of the pulp chambers and embedded in paraffin. Sections were stained with hematoxylin and eosin. With six specimens, serial sections of the entire pulp were cut. An examination of these sections indicates that, if the same procedure had been adopted for the entire series, a considerably larger number of lesions would have been found. From a

number of specimens, sections were also stained by the Gram-Weigert method for bacteria, but with negative results.

As in our previous study, all these teeth (with the exception of tooth no. 33, noted in the protocols below) were *clinically vital*, with pulps presenting neither discoloration nor odor on opening the pulp chamber, and without actual extension of caries to the pulp chamber. From six specimens, owing to technical difficulties, satisfactory sections were not obtained. Three teeth were free from caries or pericemental lesions, and these presented histologically normal pulps. Of the remaining forty-one teeth, thirteen showed pyorrhea alone, five were invaded by caries without pyorrhea, and twenty-three exhibited evidences of both caries and pyorrhea. As in our previous paper we include, under caries, teeth with filled cavities where the decay has apparently been arrested.

Descriptions of the fifty vital teeth we studied, and statements of findings relating to them individually, are given below.

Descriptions of the vital teeth, with statements of the corresponding findings

1. Cuspid. Caries; pyorrhea. Pulp normal.

2. Cuspid. Caries; pyorrhea. Pulp normal.

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6. Molar. Caries; no pyorrhea. Section of the pulp shows an area of diffuse lymphocytic and plasma-cell infiltration in one cornu, with edema and congestion in this portion. Otherwise the pulp appears normal. (See *figs. 2* and *3*.)

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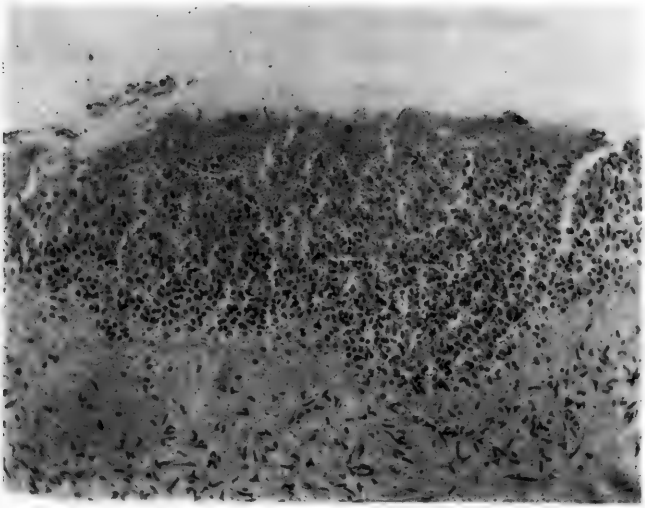

FIG. 1. AN AREA OF SUBODONTOBLASTIC INFILTRATION WITH LYMPHOCYTES. (TOOTH NO. 36)

FIG. 2. AN AREA OF INFLAMMATORY INFILTRATION AND CONGESTION IN ONE OF THE CORNUA OF A MOLAR. (TOOTH NO. 6)

8. Incisor. Caries; pyorrhea. There is an area of fatty tissue in the coronal portion on one side, extending half-way down the pulp; below this is an area of infiltration, with lymphocytes and a few plasma cells extending from the odontoblastic layer inward for one-third of the thickness of the pulp. There are some heavy fibrous bands and one small calcareous nodule in the radicular portion. The pulp is congested.

9. Molar. Pyorrhea; no caries. Fatty change in one cornu; otherwise normal.

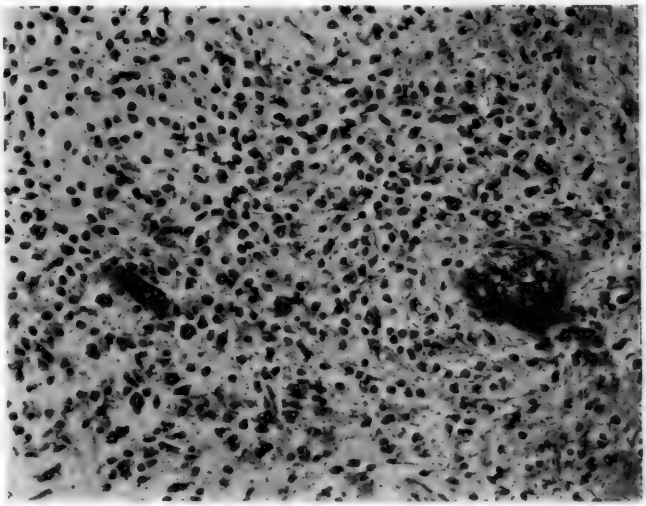

FIG. 3. A PORTION OF THE LAST PRECEDING (*fig. 2*), MORE HIGHLY MAGNIFIED, SHOWING THE MONONUCLEAR CHARACTER OF THE INFLAMMATORY CELLS. (TOOTH NO. 6)

10. Canine. No caries; no pyorrhea. Pulp normal.

12. Molar. Extensive caries; no pyorrhea. Section of the pulp shows an area of diffuse lymphocytic infiltration beneath the odontoblastic layer; otherwise normal.

13. Molar. Extensive caries; pyorrhea. Section of the pulp shows nothing abnormal.

14. Canine. Pyorrhea; no caries. Pulp normal.

16. Cuspid. Silver filling; some pyorrhea. One small area of lymphocytic infiltration in the coronal portion of the pulp; otherwise normal.

17. Molar. Extensive filled caries; slight pyorrhea. The pulp shows general fibrosis, dense connective tissue being found in all parts of the section. There is one large irregular calcareous mass in the coronal portion, and a large area of lymphocyte and plasma-cell infiltration beneath the odontoblastic layer; a small, more circumscribed, area occurs internally to the preceding. Some endothelial cells are present in these areas.

18. Molar. Artificial crown. Pyorrhea. Pulp appears normal.

19. Molar. Severe pyorrhea, crown much worn, no caries. Pulp is composed of dense fibrous tissue; infiltration in many areas with lime salts.

21. Molar. Caries; pyorrhea. There is hyperplasia of odontoblasts in the coronal portion of the pulp, the odontoblastic layer being in places four or five cells deep. There are several large irregular calcareous masses and one small circumscribed area of lymphocytic infiltration, in this portion. The radicular portion is composed of dense fibrous tissue, diffusely infiltrated with lime salts.

22. Canine. Pyorrhea; no caries. There is a large amount of fatty tissue in the coronal portion; otherwise the pulp is normal.

23. Canine. Slight caries; pyorrhea. Pulp normal.

24. Molar. Caries; pyorrhea. Pulp normal.

25. Incisor. Large filled cavity. There is considerable fatty tissue, also fibrosis, in the coronal portion; otherwise the pulp is normal.

26. Incisor. Severe pyorrhea. Small filled cavity. Pulp normal.

27. Incisor. Severe pyorrhea. Small filled cavity. The pulp shows general fibrosis, with areas of fatty tissue. The odontoblastic layer in the coronal portion is thickened and there is some lymphocytic infiltration beneath it.

28. Incisor. Severe pyorrhea. Small filled cavity. Pulp normal.

30. Molar. Filled caries; pyorrhea. Pulp normal.

31. Molar. Normal. Pulp shows no change.

32. Molar. Filled caries. "Floating in pus." Section of the pulp shows extensive fibrosis and fatty change; diffuse subodontoblastic infiltration with lymphocytes and plasma cells; some small irregular calcareous nodules in radicular portion.

33. Canine. Caries, extending to the pulp chamber. No pyorrhea. Grossly the pulp appears to be normal in the lower part, but a small drop of pus occupies the upper part of the pulp chamber.

Microscopically, the coronal portion of the pulp shows necrosis and infiltration with polymorphonuclear leucocytes; just beneath this is an area of intense congestion. As we further approach the root, there is found a large area densely infiltrated with plasma cells, and large endothelial

FIG. 4. AN AREA OF NECROTIC TISSUE WITH POLYMORPHONUCLEAR LEUCOCYTES; CORONAL PORTION. (TOOTH NO. 33)

FIG. 5. SMALL MASSES OF LIME SALTS IN A GRANULOMATOUS AREA. (TOOTH NO. 33)

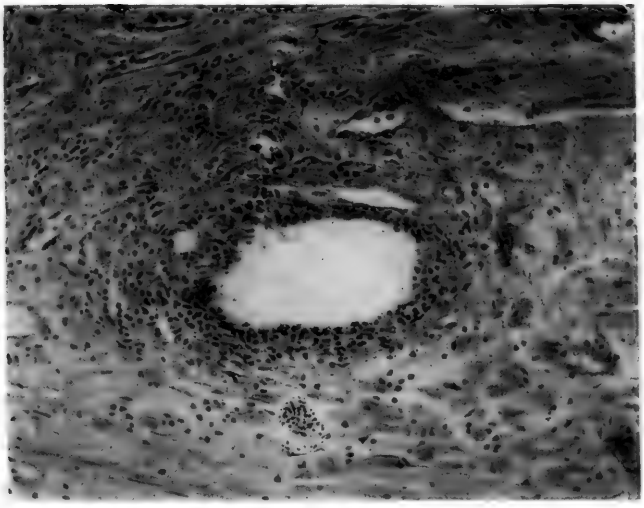

FIG. 6. PERIVASCULAR INFILTRATION WITH LYMPHOCYTES AND PLASMA CELLS, SURROUNDED BY A FIBROBLASTIC REACTION. (TOOTH NO. 33)

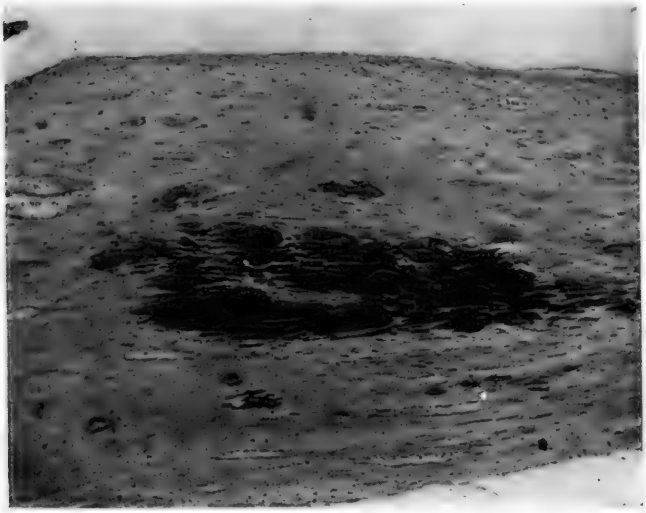

FIG. 7. CALCIFIED FIBROUS TISSUE IN THE RADICULAR PORTION. (TOOTH NO. 33)

phagocytes, which spread apart the fibrous bundles; several amorphous masses of lime salts are scattered through this area. The connective tissue of the radicular portion is dense and fibrous; one large vessel is surrounded by a zone of lymphocytes and plasma cells, and nearby there are nests of proliferating fibroblasts. As we approach the root tip, the pulp tissue shows extensive diffuse infiltration with lime salts. (See *figs. 4, 5, 6* and *7.*)

(*Since the pulp chamber had already been opened by caries, this tooth should not be included in the series proper. The description and corresponding photomicrographs are included in this paper because this one pulp shows all stages in the process of natural devitalization.*)

34. Incisor. Slight caries; pyorrhea. Pulp normal.

36. Molar. Pyorrhea; caries; abscess between the roots. One cornu of the pulp shows an extensive area of subodontoblastic infiltration with lymphocytes and plasma cells. There is general fibrosis of the pulp with fatty change. There are several large irregular masses of lime salts in the coronal portion and two distinct pulp nodules in the root. (See *fig. 1.*)

37. Molar. No caries; pyorrhea. Pulp normal.

38. Molar. No caries; pyorrhea. The coronal portion of the pulp shows a very extensive diffuse infiltration with lymphocytes, plasma cells, and occasional polymorphonuclear leucocytes. The pulp shows general fibrosis, with one large pulp nodule and a number of small irregular calcareous masses. (See *figs. 8* and *9.*)

39. Molar. Large lateral cavity; no pyorrhea. The pulp shows several small areas of lymphocytic infiltration in the coronal portion. There is some fibrosis, and a few small irregular masses of lime salts are found.

40. Molar. No caries; pyorrhea. Pulp normal.

41. Molar. No caries; pyorrhea. Several small irregular calcareous masses are found in the pulp.

42. Molar. No caries; pyorrhea. The pulp is completely fibrosed and extensively infiltrated with lime salts.

44. Incisor. Pyorrhea; no caries. The pulp consists of a small amount of dense fibrous tissue enclosing numerous large irregular masses of lime salts. The pulp is almost completely calcified.

45. Incisor. Pyorrhea; no caries. The pulp shows some small irregular calcareous masses but is otherwise normal.

46 Molar. Large filled cavity; pyorrhea. There is one large pulp nodule in the coronal portion and extensive calcification in the radicular portion; no inflammatory reaction but some fibrosis.

47. Molar. Pyorrhea; no caries. Pulp normal.

48. Incisor. Filled cavities; pyorrhea. Pulp normal.

FIG. 8. ISLANDS OF CALCIFIED MATERIAL IMBEDDED IN DENSE FIBROUS TISSUE. (TOOTH NO. 38)

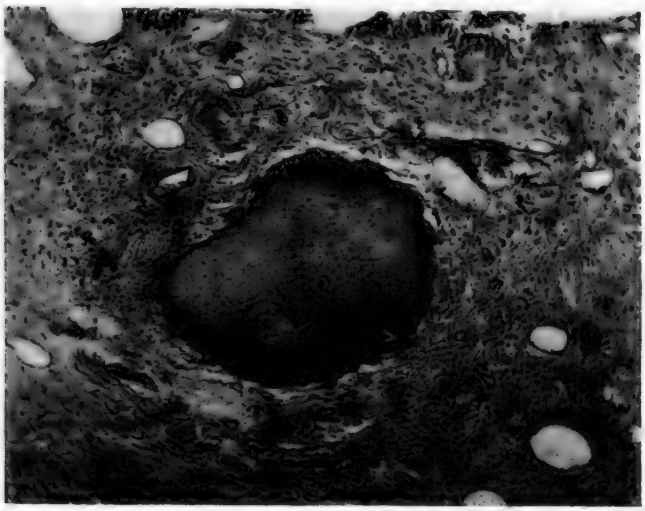

FIG. 9. A PULP NODULE IN DENSE FIBROUS TISSUE. (TOOTH NO. 38)

49. Incisor. Filled cavity; pyorrhea. Pulp normal.

50. Incisor. Filled cavities; pyorrhea. At one point there is an area of lymphocytic infiltration in the coronal portion, with fibrosis and fatty change throughout the pulp.

III. DISCUSSION OF THE FINDINGS

The lesions observed fall naturally into two classes, namely, (1) inflammatory cellular infiltrations, and (2) secondary or degenerative changes, including fibrosis, calcifications, and fat accumulations. The first alone, of course, can be considered as direct evidence of bacterial activity.

The inflammatory lesions can be best characterised as "miliary granulomata," since they are very small (not visible to the naked eye), usually rather sharply circumscribed, are accompanied by very little destruction of tissue, and exhibit only mononuclear leucocytes, namely, lymphocytes and plasma cells, such as we are accustomed to associate with progressive chronic inflammations in other parts of the body. In only two cases have we found polymorphonuclear leucocytes; in one of these, as noted, the pulp was exposed, and in the other the pus cells were very much in the minority.

These lesions, save for their limited extent, are practically identical with the earliest lesions in the subgingival region in pyorrhea, and the periapical tissues in root "abscesses," as we have described them in a previous paper (2). They are also identical with the majority of the lesions which occur in rabbits experimentally inoculated with dental streptococci. Miliary granulomata were found most frequently in the coronal portion of the pulp, usually just beneath the odontoblastic layer, but also at times free in the pulp tissue, especially in the cornua of molars.

The various lesions which we have included under the heading of secondary or degenerative changes have been well described before, especially by Hopewell-Smith, who ascribed them to a variety of general causes, but especially to senescence. Unfortunately, we have failed to keep a record of the ages of the patients from whom these teeth were extracted, and the series studied is too small to allow us to follow all of these changes in their natural sequence. Nevertheless, we rather believe that these changes are the result of the inflammatory

reactions just described, and that they represent repeated lesions of a granulomatous character which have undergone spontaneous healing. It is self-evident that the teeth of elderly individuals are more likely to have suffered from repeated infections than those of younger persons.

Fibrosis of the pulp is readily recognized, since the connective tissue of the pulp is normally of an embryonic or mucoid character. We have set down, as fibrotic, all pulps showing any considerable amount of collagen with connective tissue cells of the adult type; although many of the pulps showed a few strands of adult white fibrous tissue in the radicular portion without further change, and were not included as fibrosed.

Fibrosis, as is well known, is a sequel of inflammation wherever it occurs. It is the final stage of tubercle and gumma, of the submiliary nodules of rheumatic myocarditis, and of all granulomatous inflammations which undergo healing. Even the fibroses of appendix and tonsil, of breast and prostate, formerly considered as degenerative changes accompanying senescence, are now generally considered rather as the result of repeated inflammatory reactions, due to bacteria, to which these tissues have been subjected during life. We feel sure, therefore, that the fibroses we have observed in the dental pulp are the scars of previous granulomatous inflammations produced by microörganisms.

The extensive calcifications which occur in the pulp need further study, and an elaborate discussion is beyond the scope of this paper. They have been repeatedly described before, and have been explained in various ways. They have been considered as an aberrant secretion of the dentinogenetic cells, analogous to the callus formed by injured bones; but this is evidently not the case, since we have found them most frequently far from the odontoblastic layer surrounded by adult connective tissue. In fact, in most cases the lime appears to be deposited in the connective tissue fibers themselves. Again, reasoning by analogy from the pathology of other tissues, we believe that these calcareous deposits are also the result of a previous infection, for they occur frequently in tubercles and gummata. We have previously described similar deposits of lime salts in the connective tissues of the peridental membrane in both pyorrhea and apical granulomata. In this connection we might recall that Rosenow has described a phe-

nomenon which we have also observed, namely, a rapid and rather extensive infiltration with lime salts in some of the lesions produced in rabbits by inoculation with non-hemolytic streptococci; these occur especially in the voluntary muscles.

The fatty changes which we have observed are not fatty degenerations or infiltrations, but deposits of fatty tissue of an adult type in areas of the pulp tissue, the fat cells appearing as hollow spheres with the nucleus in each pushed to one side, and the tissue presenting the areolar appearance of fat tissue as it occurs in other parts of the body. We have found no description of this condition and cannot explain it. The fat was also found associated with fibrosis, and may represent an attempt to fill the space left in the pulp chamber by the shrinkage of the scar tissue formed there. Deposits of fatty tissue accompany chronic or fibrosing inflammations in other parts of the body; for instance, one frequently finds a sclerosed or obliterated appendix embedded in a fatty meso-appendix, even in lean individuals.

The number of teeth studied is too small to warrant quantitative comparisons, either with the bacteriological studies previously reported or between the various groups in the present series, but we have expressed the results of our study quantitatively in the following table:

TEETH		RESULTS OF HISTOLOGICAL EXAMINATION				
Condition	Number examined	Normal	Inflammatory infiltrations	Fibrosis	Calcification	Fat
Normal	3	3				
Pyorrhea only	13	5	1	4	6	2
Caries only	5	0	4	3	2	1
Both caries and pyorrhea	23	6	9	11	9	6

IV. GENERAL CONCLUSION

Thus, we have found active inflammation in fourteen pulps from forty-one infected teeth, or 37 per cent—ample confirmation of the opinion, previously arrived at from bacteriological studies, that the pulp may be (a) invaded by microörganisms long before it is actually exposed by caries, and may be (b) repeatedly injured long before it actually undergoes necrosis.

V. LITERATURE CITED

(1) 1919 HENRICI, ARTHUR T., AND HARTZELL, THOMAS B. The bacteriology of vital pulps. JOURNAL OF DENTAL RESEARCH, i, p. 419.

(2) 1917 HENRICI, ARTHUR T., AND HARTZELL, THOMAS B. The microscopic anatomy of chronic periodontitis and the pathogenesis of dental root cysts. *Journal of the National Dental Association*, iv, p. 1061.

COMMENT ON McCORMACK'S "PLEA FOR A STANDARDIZED TECHNIQUE FOR ORAL RADIOGRAPHY"[1]

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In the last preceding issue of the JOURNAL OF DENTAL RESEARCH (p. 467), there appeared a paper by Mr. F. W. McCormack that, in many respects, is probably the last word in dental x-ray work. Such work should be a great inspiration to all other workers in this field; and many can but envy McCormack's wonderful ability and, equally, his most wonderful equipment and opportunity. Speaking for myself, I certainly do envy him in all of these respects.

That McCormack and his collaborators can diagnose and differentiate periodontitis, alveolitis, necrosis, osteosclerosis, osteitis serrata, osteogenesis, by means of the ray is simply wonderful, and only goes to prove that team work, ability, and an insatiable desire for work, will often accomplish the apparently impossible. I am satisfied that the work of this far-western group has opened the eyes of many x-ray operators to possibilities heretofore undreamed of. Those who heard Dr. Pollia at the Boston meeting of the National Dental Association (last August), were fortunate indeed. Rarely does one meet a man his equal in facility for conveying information; and he gave his hearers much to think about. However, there are certainly a number of features in the paper—features which have nothing to do with the pathological findings, but with the mechanical and physical properties of the ray—which are so contradictory to each other, and which in some cases are so radically different from the *generally accepted facts*, that it appears to me they should not be allowed to pass without comment.

Many interesting (?) points will be ignored, for this brief review can cover the "high spots" only. I am writing in no spirit of carping

[1] McCormack: JOURNAL OF DENTAL RESEARCH, 1920, ii, p. 467.

criticism. I grant unto others greater degrees of ability, but to none a greater interest in the welfare of dentistry.

McCormack has made certain didactic statements that I do not believe are correct. I shall merely call attention to what seem to me to be errors. I am not infallible—I have made many mistakes in the past, and I may be wrong now; but if I am wrong, scores of others are with me; and if wrong, we all are more than anxious to be shown our error. If McCormack is wrong, I am sure he also will be glad to have the errors pointed out, for, of course, he is working for the good of the cause.

McCormack gives to the world what he calls *standard technique*. By that he necessarily means technique that is governed by fixed rules. A *fixed rule* is one from which there is no deviation. We are told that "to standardize a Coolidge-tube technique, five factors must be kept constant." Then we are also told that there must be "(3) a definite period of exposure sufficient for the *majority* of patients when exposures are made of the same corresponding area." Here then is a standardized technique which is good only for a majority, say from 51 to 60 per cent of our patients, and for the other 49 or 40 per cent, we must test each case, and vary the time accordingly. And this is called "an exposure technique that is a definite procedure in all cases."

After the skiagraphs have been taken by this *standardized technique*, the films are developed in a tray by sight in order, *we are told*, that "if there are any variations in the different exposures of one case, she (the dark-room technician) can readily control them, and thus add greatly to the attainment of uniformity."

One must have a remarkably vivid imagination to be able to include in a standard technique the developing of films one at a time and by sight. A "standard technique," as interpreted by the real meaning of the words, calls for the suspension of the nineteen films by one set of clips in the developer for a certain definite time—that and nothing else.

Again we are told, by McCormack, that he has "*reproduced* sets of radiograms after intervals of three years." This statement must surprise most of us. Even the editor of the *Dental Items of Interest* —usually considered to be a well-posted man—could not have been aware of it, or he would not have written such an editorial as appeared

in the July number of that journal, in which he *apparently* gives credit to Dr. F. T. Van Woert for having devised the only practical method of accomplishing this feat.

Is it not strange that, in such an article as McCormack's, in which so much space is given to certain details, the author failed to explain just how the "reproduction three years later" was accomplished, especially as no one previously had ever claimed to do this, and particularly since, in order to *reproduce* films from time to time, certain special appliances must be designed for the purpose.

Referring to McCormack's disposition of the shadows of the malar bones, I must admit that I cannot comprehend his explanation. In one instance, we have a molar root, a malar bone and a target—all three in a straight line with each other, and the target twenty-four inches distant. By all known laws, if one moves the target, keeping, it in a straight line with the other objects, to a distance of forty inches, the three objects will still be in a straight line How under these conditions, the rays can be "shot under the malar process and strike the molar apices directly," is too much for me.

McCormack's explanation of this phenomenon, using two fingers as he suggests, is not pertinent to the case in hand. He tells us that "you will be able to see the rear finger quite clearly after a very *slight motion* of the hands," which no one will doubt; but with the malar bone it is a different matter, for neither the root nor the malar bone is given any "slight motion" in order to shoot the rays under the malar bone. It is very evident that some other explanation of the phenomenon is due McCormack's readers.

So much for the standardization. Now for some of the conditions "that may be recognized in, and correctly interpreted from, accurate radiograms." I shall consider them serially, as they appear in McCormack's paper.

Plate 1 (l–Z).—"Lower third molar; dark area around apices probably from superimposition of the overlying muscular tissues." *Comment.* How the superimposition of the muscular tissues upon a *normal* lower third molar, deeply imbedded in the bone as it is, can make the area in question more *radiolucent* than it would be without these tissues being superimposed, is beyond my comprehension. In other words, if McCormack's interpretation is correct, such a normal apex

of itself would naturally be radiopaque; but place muscular tissue over it, and it at once becomes radiolucent. I think the phenomenon observed should have been accompanied by a different explanation.

Plate 2. (8).—"Deep filling probably involving pulp canal." *Comment.* Such a film cannot possibly indicate a *deep filling.* The depth of no filling can be shown in a skiagraph. A thin veneer upon the surface would cast the same kind of shadow. Every "oral radiographer" should be made aware of this fact.

(10).—"Lower right first bicuspid; vital tooth." *Comment.* No skiagraph can disclose whether a tooth is vital or not. Both a vital pulp and a putrescent pulp appear as dark lines upon a film.

Plate 3. (13).—"Lower first molar; deep fillings, probably involving the pulp chamber." *Comment.* Here again it is impossible to decide whether the fillings are deep or merely veneers—both cast the same kind of shadows upon a film. As for the probability of involvement of the pulp chamber, that is purely conjectural. There is nothing to back that opinion, and it should be taken for what it is worth.

(17).—"Pulpless tooth with a partial root-canal filling." *Comment.* It is impossible to tell by a skiagraph whether or not a root canal is filled. Every *dentist* of x-ray experience knows that it is possible to fill a root canal, and *fill it thoroughly,* with radiolucent material, and that such a filling will not cast a shadow upon a film. Although *every commercial x-ray worker should be aware of that fact,* probably very few are.

Plate 7. (53).—"Lower right first molar; apparently vital, but with a deep filling; caries under the filling." *Comment.* The skiagraph cannot possibly indicate whether the pulp is vital, *dead and sterile,* or putrescent. Caries may be under the filling, maybe not. Skiagraphs cannot disclose the relationship of caries to a filling.

(55).—"Lower right second and third molars; vital." *Comment.* Again we insist that vital pulps cannot record distinguishing marks upon a film.

Every one of the foregoing contentions can be readily substantiated, but, at present, time and space forbid.

As I said before, I know that a world of experienced dentists are of the same belief in this relation as I am. If we are wrong—if McCor-

mack can readily diagnose vital teeth from pulpless teeth; if he can differentiate a surface veneer from a deep filling; if he can tell a radiolucent root-canal filling from a radiopaque one, and so on all along the line—he should not be content with merely mentioning these acquirements; he should come down out of the clouds and tell us less fortunate ones just how to do these various things.

It is most difficult, in fact quite impossible, for any conservative dentist to decide in some cases whether a pulp is dead or alive, unless he drills into it. Consequently, he would "jump" to the use of a method for detecting such pulpless teeth, if he only had the chance.

A paper like McCormack's may do very much harm. Take the situation in which it places me, as an illustration. I have given up general practice and *pose* as a dental x-ray diagnostician. Physicians and dentists from the country 'round about, under the supposition my specialty creates, send me their patients for diagnoses. Now there is Dr. X (reader of the JOURNAL), from some little cross-roads town: he sends me a patient for a diagnosis. I report to Dr. X that I cannot tell a vital tooth from a pulpless one; that I cannot tell an infected root canal from a sterile one; that I cannot tell whether a root canal is filled or not, and that I cannot tell whether a filling is near the pulp or not. And then he throws up his hands in holy horror and says: "Well, what's the use of sending a patient to such as *you?* There's McCormack of San Francisco—*he* can do all of these things 'without batting an eye!' Why don't you 'get busy' and learn something about x-ray work before you adopt it as a specialty? Goodnight, Dr. Kells."

Thus, it seems to me, it is incumbent upon McCormack to explain to us less fortunate ones how he can differentiate between a vital pulp and an empty canal; how he tells that a filling is a deep one and not merely a veneer; so that we can render our patients the same service that he does his.[2]

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[2] McCormack's reply follows this criticism: JOURNAL OF DENTAL RESEARCH, 1920, ii, p. 557.—(Ed.)

REPLY TO KELLS' COMMENT ON McCORMACK'S "PLEA FOR A STANDARDIZED TECHNIQUE FOR ORAL RADIOGRAPHY"[1]

FRANKLIN W. McCORMACK

San Francisco, California

On behalf of my collaborators and myself, I desire to thank Dr. Kells for the kind things he has said of us and our work in the criticism on pages 551–555 of this issue. Team-work, plus the advantages of constructive criticism and, at times, even of carping criticism "for differing so radically from the generally accepted facts," has so closely welded together our group of co-workers[2] that our objective is clear to us, but may not always be evident to our critics. We ask the indulgence of those of the members of the dental profession with whose opinions we appear to differ radically. Their objective and ours is presumably the same; the only differences are probably differences in the methods by which each group has undertaken to reach this objective.

We are fortunate, as a group, in being able to work together congenially for the common good, although there are great differences of opinion among us over many of the various questions that have arisen from time to time. The common ground on which we stand together is our unanimous belief in the importance of getting better radiography. At best, the radiogram has limitations that seem, at present, impossible to overcome. But the stimulus of working together as openminded men, to whom new ideas are not heresies, will, we hope, lead to better radiography than any we are doing now.

I hesitated a long time before publishing my paper on the shifting subject of radiographic technique. Often, in the past, I felt that a system had at last been worked out that was worthy of publication,

[1] Kells: JOURNAL OF DENTAL RESEARCH, 1920, ii, p. 551.

[2] Some of the members of the "group of co-workers" were named in the author's original paper on this subject: JOURNAL OF DENTAL RESEARCH, 1920, ii, p. 484.—(Ed.)

only to find later that the technique about which I was writing could be further improved, and that better results could be obtained by additional changes in procedure. This applies to what I published in this JOURNAL[3] and which Dr. Kells criticises. Very recently, the installation of timing devices has improved my work so much, that I should like to recall some of the things I said in that paper about accurate timing. Fortunately, there is one consolation always—we invariably did the best we could.

There is one fundamental that is not subject to change, namely, the necessity for the installation of the best possible equipment. Before finally replying to my critics, I should like to learn the kind of equipment each is using, and something of the procedure with it.

Dr. Kells writes: "Many interesting (?) points will be ignored, for this (his) brief review can cover the 'high spots' only." This may also be said of any paper that deals with so great a subject as radiography in general. The only way I can hope to convince Dr. Kells that "certain didactic statements" are correct is to show him several thousand full-denture sets of radiograms where the results I have obtained can be demonstrated visually. The truth in these "didactic statements" has been proved by over four thousand entire-denture cases now in the hands of the dental profession of California. Many of these radiograms have been shown and the technique demonstrated to visiting dentists from various parts of the country, and also in class-work in Chicago. Further, the radiographic interpretations of a large percentage of these have been verified clinically, at operation and by bacteriological investigations.

No claim was made that the technique described by me is an exact, or an absolute one; but the mechanical manipulation of equipment, tubes, and dark-room procedure, is so standardized, and the fixed rules operate with such slight deviations, that the work would become purely mechanical if it were not for the physical variations in patients. It is the study of the physical variations in patients that makes the work particularly interesting. A knowledge of anatomy is required to enable one to apply the mechanical rules to these anatomical

[3] McCormack: JOURNAL OF DENTAL RESEARCH, 1920, ii, p. 467.

variations. I have tried to simplify these rules so that only one factor, length of time of exposure, need be changed to overcome these physical variations.

Photography is a simple procedure to the amateur only. Those who have studied it most carefully realize that, by the trained eye and hand, one can get better and more uniform results in the dark-room than by the mechanical means of tank development. Tank development would be ideal if the jaws of all patients were of identical composition, but they are not. Hence, we rely upon the intelligence of the dark-room technician to overcome the variations of this factor by developing the negatives to a uniform standard density—an intelligence not obtainable with a tank.

In regard to preventing the occurrence of a radiographic shadow of the malar process over the apices of the upper molar teeth, I have to say that, if Dr. Kells will refer again to the top of page 476 of my paper, he will find there the statement that the patient should be placed in a horizontal position. The head is turned to one side and adjusted so that the malar process is uppermost, and the nose and the occipital protuberance are on a horizontal plane. The relative distance between the inferior border of the malar process and the crowns of the upper molar teeth is then ascertained by palpation. The height of the vault must be known, and its formation kept in mind. Position the film as nearly parallel to the long axis of the teeth as the vault formation will permit. If the vault is low and the malar process appears to be in the path of the rays, lower the head-rest enough to let the head incline slightly downward. This changes the positions of the teeth and malar process in relation to the tube; the malar process moves downward, but the teeth move up. With the tube thirty-six inches away, it is only necessary to produce a slight change in the relative positions of the two parts, to prevent the occurrence of a shadow of the malar process over the molar apices. This explanation amplifies my original statement, and gives to Dr. Kells the information he requests.

If the reproduction of radiograms after an interval of time is of sufficient interest to warrant the publication of a paper with half-tone reproductions of the radiograms, and photographic illustrations of the various procedures that must be used to explain the text, we

shall gladly prepare such a paper. But there are more important phases of radiography that should be considered first.

In his criticism affecting *fig. 1*, in *plate 1*, Dr. Kells is right. "Superimposition of the overlying muscular tissues" causes radiopacity, but the intermuscular spaces appear more radiolucent by contrast, especially at the angle of the mandible. Also lying above this region is the tongue and, posteriorly, the spine. Thus, there are many tissues of greatly varying densities superimposed upon this portion of the mandible. In this particular case, my records show that another plate and an intra-oral film were made to check the "phenomenon." In many cases of a suspected fracture at this point, several exposures should be made, because the "phenomenon" has been interpreted as a fracture. One case got insurance for over a year, until he was referred to me and several exposures were made that disproved the previous interpretation and diagnosis of fracture. Let me add my motto: "When in doubt, make additional exposures from different angles."

In reply to Dr. Kells' chief criticism, regarding the fact that *fig. 10* in *plate 2* is called a *vital tooth*, I wish to say that practically all our work is done on entire-denture cases; therefore, we see radiograms of many normal healthy teeth. Teeth that show no periapical changes, the pulp chambers of which have not been entered, and which exhibit no cavities or *deep* fillings, we have called *vital teeth* for want of a better term. Had we followed Dr. Kells' practice of making radiograms only of dead teeth, pulpless teeth, devitalized teeth, abscessed teeth, non-vital teeth (choose your own term), possibly we could not distinguish the appearance of a *vital tooth*.

Interpretation of radiograms must be accompanied by thought and reflection, not alone by the mere inspection of pictures. *Fig. 13* in *plate 3* illustrates this necessity. Definite periapical changes are shown at both apices. The pulp chamber does not appear to have been entered for purposes of treatment, the contacts appear to be good, the tooth does not seem to be elongated, thus eliminating traumatic occlusion as a cause; the only remaining cause would seem to be "deep fillings, probably involving the pulp chamber." For argument's sake, let us take that interpretation and follow it up clinically. One can drill into the tooth and probably get sensation.

One may even get sensation by various other tests. Which is the more valuable aid, the radiogram, or the clinical tests? That is one of the problems our group has tried to solve. So far, we think, the radiogram has the better of it. Many such teeth have been entered and treated, many have been *surgically* removed, so that the condition in the periapical region has been seen macroscopically and cultures have been made. The evidence gathered thus far shows that the radiogram tells the truth, except that the condition is usually more pronounced than is sometimes shown to be the case.

If Dr. Kells, who is a *dental consultant*, would differentiate between the terms *interpretation* and *diagnosis*, a great light might strike him. Interpretation calls the attention of the diagnostician to the changes from normal that the radiograms show; and the radiogram, plus the radiographer's interpretation, give radiographic findings. *These findings must be checked clinically and verified before a diagnosis can be made.* An important difference between Dr. Kells and myself is that his is a one-man job, from making the radiogram to operating the case, while my work is only one phase in that of a team consisting of several men. Therefore, if I make an interpretation of a "deep filling probably involving the pulp chamber," my opinion will be checked very carefully by others before it becomes a part of a *diagnosis by others.*

Regarding *fig. 17* in *plate 3*, I have to say that, in 1916, a number of dentists filled the canals of about twenty teeth (on my desk now) with the various available root-canal filling materials. All of these materials cast radiographic shadows except cotton, paraffin, and wood. (This was also done in the teeth of a dried skull, with the same results.) At the time, several dentists claimed that the radiograms had not disclosed the truth about their root-canal work; they were positive they had filled the canals to the apices. Later, it was found, when some of these teeth were extracted, that the canals had not been filled. As cotton, paraffin, and wood canal-fillings are no longer fads, we assume that a canal that is not shown by the radiogram to be filled must either contain one of these materials, or was not filled. *Although every dental consultant should be aware of this fact, probably very few are.*

Dr. Grieves' valuable paper,[4] published in the same issue as the paper under discussion, shows that he is working toward the objective of our San Francisco group. He has classified teeth into six classes, the radiogram being of indispensable aid in the differentiation of his several classes. Suppose that by a refinement of technique, the very earliest pathological changes may be shown, almost at their commencement. Would Dr. Kells regard that as an intrusion on his chosen field as a dental x-ray diagnostician, or would he accept it as a very valuable aid and use it?

For over four years we have been making entire-denture sets of radiograms for the purpose of locating the minute sites of initial caries and the effects of malocclusion, in mouths in which there were supposed to be no devitalized teeth, and in which there were, in some cases, but few fillings. It has been the study of these apparently normal mouths that has shown us many things the existence of which we did not realize before, and for which it is now our regular procedure to look. In our opinion the radiogram is many times more valuable as an aid in locating these early changes than it is in finding an abscessed tooth that has become too diseased to save. It is a far greater satisfaction to locate the site of initial caries in an otherwise good set of teeth, than to discover a large, spectacular cyst. Many of the dentists in San Francisco are educating their patients to appreciate a well placed filling in a vital tooth more than the most modern of removable bridges. The patients feel that they have had "value received" if the radiograms showed some of these almost undiscoverable sites of initial caries.

The problem of locating the incidence of caries by means of radiograms is a very important one, that some day we may have the opportunity to discuss more fully.

If the illustrations in my paper are studied, the signs of many unfilled cavities will be seen in the teeth depicted there. In the upper left second bicuspid, in *fig. 7*, plate 2, the radiogram of which was made three years ago (and which, by the way, is one of my own teeth), a small area representing initial caries will be noted on the mesial surface. It is only recently that I stopped work long enough

[4] Grieves: JOURNAL OF DENTAL RESEARCH, 1920, ii, p. 327.

to have the cavity attended to, and then not until it became painful. Caries on some tooth surfaces can be located as long as three years before the patient is conscious of any discomfort, and when the site might be overlooked in a clinical examination.

"A plea for a standardized technique" was published to help in attainment of the purpose that Dr. Kells so ably discusses in the three paragraphs preceding the last in his criticism. Physicians and dentists are justly demanding better radiography and more accurate radiographic interpretations, and it is incumbent upon radiodontists, dental x-ray diagnosticians, and commercial x-ray workers, to meet the demand. Just how we are going to do this is, at present, a personal matter with each of us. So far, each man has had to dig out the little he has learned by his own initiative and hard work. Possibly there is a way for those interested in radiography to learn from one another in a more satisfactory manner than through the agency of published discussions.

There is one difficulty with radiography, namely, that when one begins to talk or write about it, it is hard to stop. I am conscious of this difficulty now, so I shall say "Good-night, Dr. Kells," and express the hope that we may meet at an early date, where we can spend time enough, in front of an illuminating box in the study of radiograms, to become better acquainted with each other's work and conclusions.

209 Post Street

A MEDICATED TOOTH-PASTE, WITH A FULL STATEMENT OF ITS COMPOSITION

ALEXANDER LOWY

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I was asked, recently, to devise a formula for a medicated tooth-paste that would be based on scientific principles of oral hygiene. This work necessitated a careful examination of the literature of the subject, including text-books, circulars, pamphlets, formulas, etc. Since the exact compositions of many of the widely distributed tooth pastes have not been published, considerable analytical work had to be done in order to determine the character and proportion of components in these pastes that are not mentioned in the stated formulas. The larger the number of dental pastes one examines, the more one is astonished by the serious misrepresentation of some of these preparations, by the secrecy in which various formulas are enshrouded, by the omission of essential facts from public descriptions of certain pastes, and by the false or misleading statements that are offered to foster public confidence in others. A few such preparations have recently been discussed in this JOURNAL.[1]

In order to present the essential and characteristic properties of a good medicated tooth paste, namely, non-decalcifying and non-caustic action, non-poisonous effect, lack of material influence on the reaction of the saliva, effective cleansing power, non-abrasiveness, pleasant odor and taste, and important endamebicidal action, I have prepared a "milled" paste having the composition indicated on the next page, where the purpose and proportion of each ingredient in the mixture are specified.

[1] Taylor, Greeley, Limerick, Merritt, Stillman, Hyatt, Buckley and Carney: JOURNAL OF DENTAL RESEARCH, 1919, i, p. 497; also Gies and collaborators: *Ibid.*, i, pp. 507, 509; ii (1920), pp. 293, 299, 313, 511.

PERCENTAGE COMPOSITION OF "F. E. I.," A MEDICATED TOOTH PASTE

		Per cent
Precipitated chalk	(body of paste; cleanser; antacid)	58.75
Glycerine	(vehicle)	28.60
Water	(vehicle)	5.60
Starch	(binder)	1.10
Soap	(cleanser; alkalizer)	5.00
Russian mineral oil	(vehicle; lubricant)	0.25
Saccharin	(corrective; antiseptic)	0.03
Emetine hydrochloride	(endamebacide)	0.0015
Thymol	(stimulant and antiseptic)	0.015
Menthol	(stimulant and antiseptic)	0.03
Oil of eucalyptus	(stimulant and antiseptic)	0.11
Methyl salicylate	(stimulant and antiseptic)	0.11
Oil of peppermint	(stimulant and antiseptic)	0.40
		99.9965

This tooth-paste is called "F. E. I." (first eliminate infection) and is manufactured by the Preventol Laboratories, Pittsburgh, Pa. I believe it meets the requirements of oral hygiene and that it will be found to be consistently as useful as the results of preliminary tests promise for it. A clinical study of the paste is now in progress, the results of which will be reported at our earliest opportunity. Dentists are invited to prepare and test this paste for themselves; or, upon request, amounts of it sufficient for clinical investigation will be forwarded to them.

PROGRESSIVE DENTISTRY AND STOMATOLOGY

3. The Problem of Devitalized (Dead) Teeth[1]

JOSEF NOVITZKY[2]

San Francisco, California

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I. DANGERS ARISING FROM THE RETENTION OF DEVITALIZED (DEAD) TEETH

For several years devitalized teeth have stood in the forefront of the problems in modern dentistry. Writings on the subject have been numerous; yet the opinions expressed have been so divergent as to leave the busy practicing dentist very much in the dark. In view of this situation, the following summary is offered in the hope of helping to solve the most important problem in modern dental practice. The conclusions here stated have been attained by devoting at least half of each day, for over twelve years, to laboratory work and research in connection with problems arising from dead teeth.

In 1915 the writer pointed out the kinds of pathological changes that usually were shown around the root ends of devitalized teeth

[1] The two preceding units in this series of reviews were published, in the Journal of Dental Research, by (1) Gies, i, p. 525; and (2) Merritt, ii, p. 77. A fourth unit, by Rhein (p. 579), follows and discusses this one. A fifth unit, by Novitzky (p. 585), follows and replies to the remarks by Rhein.—(Ed.)

[2] The anatomical and histological portions of the work were done in the Medical Department of Leland Stanford, Jr., University. To Dr. F. E. Blaisdell, Professor of Surgery in the Medical Department of Leland Stanford, Jr., University, I am indebted for the photographs and the photomicrographs used in this review. To him I am also greatly indebted for invaluable guidance and assistance in the research in which I am engaged.

when examined with the roentgen ray. Bell's palsy and Ludwig's angina were shown to be due frequently to inferior-dental-canal infections resulting from devitalized teeth. It was shown, also, that the removal of devitalized teeth by the common method of extraction, without a thorough removal of diseased structures surrounding their root ends, might result in a low-grade suppuration during the years following extraction, with dangerous systemic sequelae. It was suggested that, when radiographic study indicated involvement of an alveolar process or of the jaw proper, the condition could be remedied by lifting and retracting the gums and periosteum, removing the outer plate of bone over the tooth roots, and chiseling away or curetting out the necrosed structures under direct vision.

Further investigation disclosed the multiplicity of serious systemic sequelae that result from devitalized teeth and led to the conclusion that all such teeth should be removed from the jaws. The dangers from the retention of devitalized teeth appeared to be so great as to make the removal of them seem to be a common-sense preventive measure. This conclusion was strengthened by examinations of hundreds of devitalized teeth showing that every one of such teeth, if left in the jaws, was infected within six months of the time of devitalization.

The main point in opposition to this conclusion was the contention that a devitalized tooth was not necessarily a dead tooth—that the human tooth had two sources of nourishment or life, the pulp and the pericemental membranes. But the only source of life and growth is the pulp. A pulpless or devitalized tooth is in every sense of the word *dead*, for its only source of nourishment has been cut off. The tooth receives no nourishment from the pericemental membranes. Normal human cementum, as has been repeatedly shown, is structureless. It is a non-vascular, non-genetic, calco-matrix formation—a cementing substance laid down in lamellae on the root from the cementoblasts of the tooth socket.

The accepted theory is that lacunae, when present in cementum, have been caused by the imprisoning of young osteofibroblasts during an excessive formation of cementum caused by irritation. Canals for collateral blood vessels through the cementum into the pulp are not common. They are undoubtedly an anomaly of structure or a

result of trauma during the development of the tooth root. The openings occasionally seen in the external lamellae of cementum, which appear to penetrate the outer lamellae, have been confused with canals for nutrient arteries; but they are in reality openings containing the partially calcified ends of Sharpey's fibers. Even if the protoplasmic fluid that probably passes part way into the cementum of normal teeth from the cells of the dental socket, could proceed to or penetrate the granular layer of Tomes, it would not be sufficient to maintain vitality in tooth dentin.

II. THE AUTHOR'S SURGICAL METHOD FOR THE THOROUGH REMOVAL OF DEVITALIZED (DEAD) TEETH AND ASSOCIATED FOCI OF INFECTION

With the decision that all devitalized teeth should be removed from the jaws because they are *dead*, subject to infection, and apt to lead to serious systemic ills, came the problem of *how* to remove them. Extraction, as ordinarily practised, was insufficient, as shown by the many dangerous focal infections existing long after tooth extraction. Extraction followed by blind curettement has also proved insufficient. The only safe method is the thorough removal of dead teeth, and the associated infected regions or foci of infection, in accord with modern methods of bone surgery. For such thorough removal the following operation was devised.

The region to be operated upon is first anesthetized with novocain so that the work may be done with no pain and very little shock to the patient. Then the outer plate of bone is exposed, for a little more than the length of the tooth root, by raising and pulling back a triangular flap of gum and periosteum with its apex at the gingival margin of the necrotic root. If it is necessary to gain more space for operating, it may be necessary to pull back gum and periosteum from the healthy tooth on each side of the necrotic one. If this is done, great care must be exercised to suture the gums in their original position at the end of the operation.

Next, part of the outer plate of bone over the infected root is outlined with chisel and gouge, and then removed so as to expose the cancellous bone and the tooth root. If the part of the buccal plate thus removed does not extend so far as the end of the tooth root, the

tooth should be hooked out sidewise before apical curettement and exploration. If the buccal plate is removed over the entire root length, the tooth may be hooked out either before or after apical curettement and exploration. If a cavity is found beneath the roots of a multi-rooted tooth, the tooth and the alveolar septum should be removed with a chisel.

The inner plate of bone should be left intact whenever possible, since bone regeneration does not take place so well in the inner as in the outer plate, when both plates are removed. The inner plate of bone in the upper jaw, when the antrum is involved, may be cut away enough to permit the inner flap of mucous membrane and periosteum to be drawn over to meet the outer flap.

An incision involving the antrum is sutured. The cavity drains through the natural ostium into the nose. Gauze packings are not used except as mechanical blocks to hemorrhage. The cavity may be thoroughly irrigated, if necessary, five or six days after operation by inserting a cannula through the flap from the mouth, or through the thin plate of bone under the inferior turbinate of the nose. For extensive surgical work on the antrum, the incision should take in several teeth on the affected side.

After the infected granulation tissue and necrotic debris have been removed, the edges of the bone should be smoothed with chisel or curette so that there will be no sharp edges to retard post-operative repair. Finally, the periosteal flap is sutured to the inner margin of the mucous membrane.

Figs. 1, *2*, and *3* illustrate the features of the operation outlined above. *Figs. 4* and *5* throw light on the nature of cementum, and present convincing evidence that new cementum may be deposited on dead cementum. Such deposition retains dead teeth in their crypts and prevents their exfoliation.

Explanations of the illustrations

Fig. 1 indicates how the incision in the gums should be made in the operation for the removal of the upper first molar. This incision should allow a generous margin of mucous membrane and periosteum at *A*, in order to obviate post-operative recession of the soft tissues from about the necks of the teeth on both sides of the operative wound. The terminals of the lines of

incision are indicated by *B*. These may be extended anteriorly and posteriorly, if a larger approach is rendered necessary by unanticipated complications. The incision as shown would ordinarily be ample for the removal of the tooth and the necrotic alveolar process, and for the exploration of the floor of the antrum immediately above the root ends.

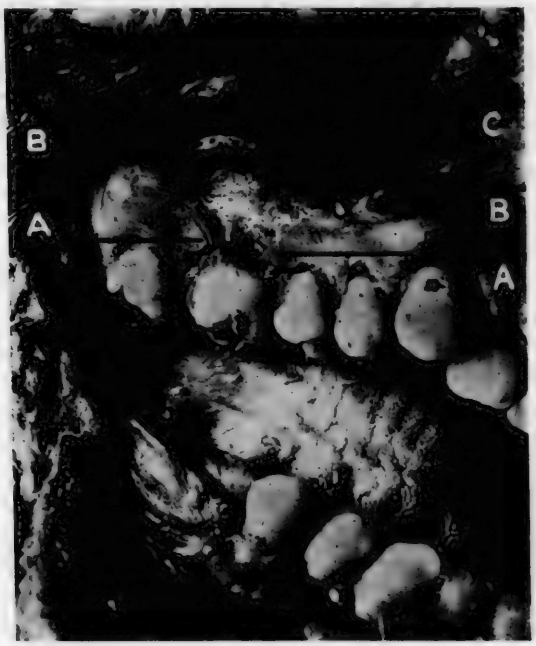

FIG. 1. SHOWS HOW THE INCISION IN THE GUMS SHOULD BE MADE FOR THE REMOVAL OF THE UPPER FIRST MOLAR. SEE PAGE 570

The gingival edge of the flap, *C*, is pared, after the incision has been made, in order that there may be a freshly cut surface to be sutured to the lingual side of the wound at the close of the operation. The periosteum and soft tissues composing the flap are lifted free of the bone and held back with a retractor. Now, that part of the outer plate of the process that lies over the buccal roots is outlined with chisel and gouge, and removed in one piece. The buccal roots are then exposed in situ in the alveolar process. Each buccal root should be cracked free from the root crown by a smart tap with mallet and chisel, and hooked out sidewise. The tooth crown held

only by the long lingual root is still in position. At this stage of the operation, hemorrhage should be under control, so that, with direct access and vision, the apical region of the buccal roots may be curetted thoroughly and examined for perforations into the antrum.

If no perforation leading from the buccal roots is discovered, the side of the lingual socket next to them should be enlarged with the gouge, and then the remaining root with the tooth crown should be elevated from the socket. Should a lingual perforation be discovered, the antral membrane may be left intact, if this is desirable, as the alveolar process is lifted away from that membrane. Frequently, pus or exudate from a dead tooth drains through the thin floor but will not perforate the membrane. When it does perforate the membrane, the latter is commonly much thicker and more fibrous than in its normal condition. Polypoid tissue may often be found involving the antral cavity immediately above the dead roots. After all the infected granulation tissue and necrotic debris have been removed, the edges of the opening in the bone should be smoothed with chisel or curette, since sharp bone edges retard post-operative repair. Finally, the periosteal flap, *C*, should be sutured to the inner margin of the mucous membrane.

Fig. 2, *A*, indicates the lines of incision for the removal of a lower right second bicuspid. *B* is the flap of mucous membrane and periosteum. *C* indicates the root of the bicuspid after the outer plate of the mandible has been cut away. The tooth is shown ready to be removed sidewise through the opening in the outer plate.

Fig. 3 pictures a tooth socket after the tooth has been removed. It shows how there is direct access to the pathological cavity at *A*, which is in communication with the inferior dental canal. The stretched and tightly adherent membrane, *B*, is seen surrounding the orifice of the mental foramen. This membrane incloses the nerve and blood vessels in its sheath. In this case the incision is large and the soft structures over the vital roots anterior to the second bicuspid are drawn back, in order to permit the careful dissection away, and the stripping, of structures from the mental foramen, and also to make it possible to work without severing the mental nerve or blood vessels. If any structures that are no longer normal are allowed to remain, they will continue a low-grade suppuration, and result in atrophy of the surrounding bony parts and in secondary metastatic sequelae. Hence, it is commonly necessary to pick away bone comprising the wall of the inferior dental canal so that no abnormal structures will be allowed to remain.

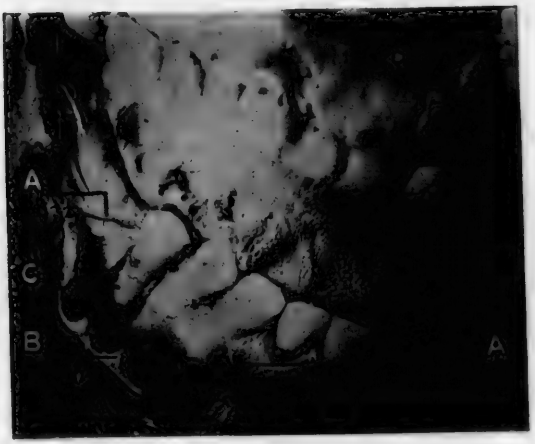

FIG. 2. INDICATES THE LINES OF INCISION FOR THE REMOVAL OF A LOWER RIGHT SECOND BICUSPID. THE TOOTH IS SHOWN READY TO BE REMOVED SIDEWISE THROUGH THE OPENING IN THE OUTER PLATE. SEE PAGE 572

FIG. 3. PICTURES A TOOTH SOCKET AFTER THE TOOTH HAS BEEN REMOVED. SEE PAGE 572

Fig. 4 shows a section through the root of a replanted tooth. Granulations are partially detached from the root stump. An area of suppuration is seen at *A*. ***This tooth had been boiled for fifteen minutes before replantation.*** At operation two years later, the tooth was found to be thoroughly septic.

FIG. 4. SHOWS A SECTION THROUGH THE ROOT OF A REPLANTED (BOILED) TOOTH

Fig. 5 shows a section of the same tooth (*fig. 4*) with old cementum at *A* deposited before replantation. Lacunated cementum at *B* was deposited after replantation. Here the layers of cementum are quite thick. In the

pericemental structure, *C*, fibroblasts are seen clustered on the edge of calcic deposits; some are apparently submerged in the calcified tissue. *D* is a region of resorption, filled in by young cementum.

FIG. 5. SHOWS A SECTION OF THE TOOTH ILLUSTRATED IN FIGURE 4, WITH OLD CEMENTUM AT *A* DEPOSITED BEFORE REPLANTATION, AND LACUNATED CEMENTUM AT *B* DEPOSITED AFTER REPLANTATION. SEE PAGE 574

III. CONCLUDING REMARKS

The writer has used with success, and advocated the employment of, the above operation since prior to 1915.

A careful pathological examination of hundreds of devitalized teeth has failed to show a single one that, six months after devitalization, was not infected.

Some have claimed that the infections invariably found in dead teeth were due to contamination at the time of removal. If this were the case the resulting cultures would generally have been of mixed strains. They were, however, commonly of a single strain. Moreover, in many cases during operation it was possible to take smears from the roots of living teeth as well as from the roots of dead ones. In such cases the cultures from the live teeth were negative while those from the dead teeth showed pure strains of pathogenic bacteria. It is a very significant fact that many of the worst cases of focal infection were found in connection with teeth which had been devitalized and treated by the most popular methods of modern dentistry. The untreated dead teeth, in many cases, had induced effects that were not so harmful as those resulting from the treated ones.

Throughout all of these investigations, it has been strikingly obvious that, in spite of the dangers of retaining dead teeth, teeth are commonly and often unnecessarily devitalized. Although dentists do not yet agree that all dead teeth are so dangerous that their removal is desirable, every dentist should realize, nevertheless, that the ill results of retaining *some* dead teeth are sufficient to render deliberate devitalization a very undesirable procedure. There is a constantly growing tendency to remove all dead teeth, and the surrounding regions of infection, as dangerous sources of serious ills.

Because of the prevalence in the dental profession of such ideas as the view that the "reattachment of Sharpey's fibers to cementum depends on scaling or curetting away the cementum until fresh cement corpuscles are exposed," and that there are "vital root apices" after tooth-pulp devitalization, I call attention here to the following significant statement by Mallory: "Lacunae are spaces containing osteoblasts which have become bone corpuscles and as such have lost their power of proliferation and they no longer play a part in the regeneration of bone."[3] Bone regeneration must come from osteofibroblasts, which are young osteoblasts, a conclusion that is taught in the laboratories of surgical pathology of the Medical Department of Leland Stanford, Jr., University.

Details of the researches mentioned above will be found in the references in the appended bibliography.

[3] Mallory: Principles of pathologic histology, pp. 65–75 (1914). W. B. Saunders Co., Philadelphia, Pa.

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[4] All the papers in this bibliography were published by Dr. Novitzky.—(Ed.)

4. Comment on Novitzky's Discussion of "the Problem of Devitalized (Dead) Teeth"[1]

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In the foregoing review, on "the problem of devitalized (dead) teeth," Dr. Novitzky states that he has devoted "at least *half of each day*, for over twelve years, to laboratory work and research in connection with problems arising from dead teeth." Forty-four years ago my father first called my attention to the danger to health and life from the retention in the jaws of teeth with non-vital pulps. The clinical evidence in support of his position largely influenced me to decide to specialize in stomatology, even before I graduated from a medical school. The solution of the problem of teeth with non-vital pulps has been the main object of my professional career, although I have taken many fishing and hunting trips meanwhile, when I managed to forget about teeth and pulps.

As soon as I could find listeners, I told them of the wonderful cures of hopeless invalids that had been effected by the extraction of infected teeth. These statements subjected me to much ridicule, for no one else in those days was taking any note of this most serious matter. I made this fight for many years, unaided except for the coöperation of my teacher, Wm. H. Atkinson.

Although my father taught me never to retain in the jaw a tooth with a non-vital pulp, my every effort for forty years has been to elaborate an operative technic that would enable dentists to make it impossible for such teeth to continue to be, or to become, etiologic factors in focal infections. Obstacle after obstacle has been overcome in this

[1] The three preceding units in this series of reviews were published in the Journal of Dental Research, by (1) Gies, i (1919), p. 525; (2) Merritt, ii (1920), p. 77; and (3) Novitzky, ii, p. 567. A fifth, by Novitzky, follows, and replies to, this one (p. 585.)—(Ed.)

endeavor, and today it can be sanely asserted that a large percentage of teeth with non-vital pulps can be so treated as to leave them free to function, without any danger of such teeth becoming factors in focal infection. This conclusion is diametrically opposed to that of Novitzky, but I place my observations, study, and experience, of forty-four years, against the twelve years of Novitzky.

Dogmatic statements carry little weight, unless they rest upon proofs, which are altogether lacking in Novitzky's papers. All laboratory research is subject to error. In order to be reliable, a result, in a clinical relation, must coincide with clinical evidence. The clinical evidence in numerous cases of metastasis and other diseases caused by streptococcus infection that apparently have been cured, after completion of scientific pulp treatment, is the strongest clinical evidence in this connection. In all such cases the x-ray has shown regeneration of alveolar process and absence of re-infection. The writer is preparing a detailed review of this subject; and, pending its publication, takes this means of informing the few hundred men who have successfully used his technic, and all others who may be interested, that the proofs of its scientific soundness and adequacy will soon be presented.

Novitzky makes the statement that examination of hundreds of devitalized teeth has shown that every one of such teeth, left in the jaws, was infected within six months of the time of devitalization. This statement is so indefinite that it is difficult to decide which aspect of it should be discussed. If the tests of the sterility of such teeth were made *after extraction*, the results were without significance, mainly because microörganisms are frequently found in vital pulps; also in the alveolar structure surrounding such teeth. Bacteriologic examinations of extracted teeth are continually menaced by possibilities of contamination. If, however, Novitzky refers to bacteriologic examinations of such teeth *while the teeth were firmly held in the alveolar process*, his observations mean that none of the teeth was properly treated.

Consider the three axiomatic principles involved in the scientific treatment of such teeth, namely, (1) the complete removal of every particle of pulp tissue; (2) the elimination of all diseased tissue in the periapical region; and (3) the hermetic sealing of the canals with a

homogeneous solid mass of base-plate gutta-percha, with which at the same time the exits of all the foramina are hermetically encapsulated. When these essential conditions are established, every outer point of exposed root cementum is successfully insulated from all the living body tissues, and therefore is free from danger of attack. Besides, every vestige of pulp tissue having been removed from within the root, and the canals having been solidly and hermetically sealed, no infection can arise from the interior of the root. According to Novitzky, circulation from the pericementum does not pass into the dentine, making infection from this direction impossible. If this statement were entirely true, the technic for the operation of saving such teeth would be much easier than it is. In that event, the non-vital dentine would be protected by living pericementum; and, where this pericementum was lacking, the exposed cementum would be insulated by the gutta-percha encapsulation.

The fact that Novitzky has failed to see the operation, for the saving of teeth with non-vital pulps, performed as here portrayed, does not gainsay the fact that such operations are successfully conducted daily by hundreds of dentists. Novitzky, and those who agree with him, persist in speaking of such teeth as "dead" teeth. While studying tooth histology in 1882 with Carl Heitzmann, I was repeatedly shown lines of protoplasmic communication from the pericementum, through the cementum, into the dentine. Most of our histologists agree that the cementum receives all necessary nutrition directly from the pericementum. At the meeting of the National Dental Association in New Orleans (1919), Dr. Box, of Toronto, Canada, showed photomicrographic slides of sections of roots which proved beyond doubt the passage of nutrient matter from the pericementum, through the cementum and the granular layer of Tomes, directly into the dentine. The large number of specimens shown by Dr. Box demonstrated that this circulation is greatest in degree in the apical half of the root. Dr. Box's findings agree entirely with clinical observations on the gradual decrease in thickness of the pericementum from the gingiva towards the apex of the root. Novitzky himself practically admits the truth of these deductions where he says (in the foregoing review): "Even if the protoplasmic fluid that probably passes part way into the cementum of normal teeth from the cells of the dental

socket, could proceed to or penetrate the granular layer of Tomes, it would not be sufficient to maintain vitality in tooth dentin."

If every vestige of organic tissue has been removed from the interior of the root, if every foramen has been satisfactorily encapsulated, and if the dentine is left in an absolutely sterile condition, it is immaterial whether any vitality remains in the dentine or not, *so long as the pericementum retains its physiologic condition.* The dentine can now be considered, from the standpoint of health, as analogous to the ideal root filling. The tooth remains a vital organ so long as the cementum receives nourishment through the pericementum. Only if and after the pericementum ceases to function, can such a tooth be correctly called a *dead* tooth.

It is of great clinical importance that this error of nomenclature should be avoided, because we frequently find dead teeth where a portion of the pericementum has been destroyed and where the cementum has assumed a true necrotic condition. Often such a tooth is retained in the alveolus because life continues in a portion of the pericementum. Such teeth have always been properly spoken of as dead teeth, have always been considered a menace to health, and their immediate extraction has always been required. The error of Novitzky's statement, that all teeth with non-vital pulps become infected within six months, must be due to failure on his part to see teeth of this kind that have received proper treatment.

The statement frequently made, that Novitzky's field of observation includes teeth treated by the technic I have taught, will not bear investigation. I have never had an opportunity to teach the technic of this operation to the profession on the Pacific Coast. No operation I know of requires as much personal clinical instruction as this one. The necessity for painstaking care, to the most minute degree, can be appreciated only by those who have received personal instruction in its details. Attempts to save time, and to avoid the trauma that follows all surgical procedures, have led many men to do operations in accordance with my principles but by means which spell failure because the so-called improvements have accomplished quite the reverse.

No one disputes the fact that, as in all surgical operations, a certain percentage of the best attempts are failures. The lack either of un-

derstanding of the situation, or, too often, of courage in the dentist frankly to tell the patient the operation has been a failure, has undoubtedly done much irreparable harm; and such failures are more apt to be seen by Novitzky than successful operations. This, however, is no reason why the people should be prevented from enjoying the blessings of the preservation, in the jaws, of that proportion of teeth with non-vital pulps which can be successfully treated so that these teeth can never become sources of infection.

Again and again bacteriologic tests of root canals ready for filling have given negative results. This statement applies also to canals where some reaming of the gutta-percha has been done months or years after the root filling had been inserted. Finally, we can show roentgenographs of teeth covering a period of twenty years (and of some for a period of thirty years, where there were no initial pictures), in which we see the signs of perfect root fillings and of alveolar structures in apparently ideal physiologic condition in the periapical region. These facts entirely refute the views of Novitzky in this relation.

It is unfortunate that, whenever new fields of observation are opened to medical research, the pendulum invariably swings too far in a radical direction. I have always been outspoken for the removal of teeth which cannot be made safe. It is time, however, that medical men unacquainted with mouth histology, and laymen as well, should understand that a large percentage of teeth with non-vital pulps may be treated in such a manner that they can be retained to function in a healthy way; and that such properly treated teeth will always remain healthy.

The removal of the buccal plate of bone, for the purpose of extracting a tooth through this orifice, has been recommended from time to time for many years. It unquestionably is a procedure of great value in certain special cases, and has been utilized in such cases at intervals by the writer. The oral surgeon is apt to forget, however, that often the future comfort of the patient is dependent on the technic of the operator. The discomfort in cases of flat mouth, as it is commonly called, warns us to be careful to do nothing that would tend to increase such a condition.

When we consider the transitory character of the alveolar structure, after it has ceased to function, we should be very certain that, in

removing the outer plate, we have not hastened the resorption of this process. Anything that tends to alter the character of the mucosa should be steadfastly avoided. It is impossible to suture the mucosa in a way to prevent development of scar-tissue. Such scar-tissue cannot be eradicated; and, if any dental prosthesis covers such scar-tissue, the latter becomes a very sensitive place in the mouth. It is questionable whether currettement of the average case requiring it cannot be done as effectively through the socket as by way of a buccal opening. In the final analysis, the individual dentist must decide what is best for each particular case. Follow-up roentgenograms of such tooth-removals should always be made.

A secondary operation is to be preferred to operations which may entail accelerated process-resorption, or à production of scar-tissue in the mucosa.

38 East 61st Street

5. Reply to Rhein's Comment on Novitzky's Discussion of "the Problem of Devitalized (Dead) Teeth"[1]

JOSEF NOVITZKY

San Francisco, California

It is a great pleasure, indeed, to learn that forty-four years ago Dr. Rhein's father taught him "never to retain in the jaw a tooth with a non-vital pulp." This stand must have been quite exceptional, because the older men in dentistry, as recently as twenty-six years ago, regarded the retention of single rooted dead teeth as the accepted practice. Other dead teeth were extracted not because of menace to health, but because of difficulties connected with operative procedure. But extraction of dead teeth, both then and in later years, frequently failed to effect cures, as I have often pointed out.

Rhein's comment has placed me in an extremely difficult position in some respects. Carefully conducted examinations, supervised by experts in university laboratories, have convinced me that all non-vital teeth are dead and, within six months of devitalization, become infected. For several years I have been challenging the world to produce a single non-vital tooth that was not infected. No such tooth has been produced. Rhein maintains that my conclusions must be due to the fact (?) that I have not seen teeth with non-vital pulps that have received "proper treatment;" and the implication from his remarks appears to be that "properly treated" pulpless teeth include only those treated by Rhein or by men who have had the benefit of his personal clinical instruction.

The so-called proper treatment is said, by Rhein, to involve "(1) the complete removal of every particle of pulp tissue; (2) the elimina-

[1] The four preceding units in this series of reviews were published in the Journal of Dental Research by (1) Gies, i (1919), p. 525; (2) Merritt, ii (1920), p. 77; (3) Novitzky, ii, p. 567; and (4) Rhein, ii, p. 579.—(Ed.)

tion of all diseased tissue in the periapical region; and (3) the hermetic sealing of the canals with a homogeneous solid mass of base-plate gutta-percha, with which at the same time the exits of all the foramina are hermetically encapsulated." The dogmatic statement that these three things are accomplished by Rhein's technic, and that they preserve a tooth with a non-vital pulp so that it can *never* become a source of infection, are supported only by the following evidence alluded to by Rhein: (a) Bacteriologic tests of root canals ready for filling have given negative results. (b) Negative bacteriologic results have been obtained where some reaming of the gutta-percha has been done after the root filling has been inserted. (c) Roentgenographs covering a period of twenty years show perfect root fillings and alveolar structures in apparently ideal physiologic condition in the periapical region.

None of this is proof of anything. (a) A negative bacteriologic test from a canal *ready for filling* means nothing. (b) Reamings of gutta-percha cannot afford evidence of the state of the tooth matrix, which is a far better culture medium than medicated gutta-percha. (c) Roentgenographs do *not* show the presence or absence of infection, nor do they always distinguish calcification from ossification. What many writers point to as a filling-in of bone is not a physiological condition but a *pathological* state. The deposition of blood salts and broken-down bone around the apex of a dead tooth should not be mistaken for newly formed bone.

In regard to my tests of the sterility of dead teeth, I should repeat that, during the surgical removal of teeth, curettings from the region underlying the root ends were removed and incubated. The curettings were removed after the mouth fluids had been blocked from the operative field and a fairly large incision had permitted direct access to the outer plate of bone, without contact with the mucosa or the tooth. After the outer plate had been outlined and lifted free, hemorrhage was arrested and sterile instruments—not used until this stage—were employed to remove tissue from the apical regions. The lack of contamination was indicated by the development of pure strains in the cultures.

I am obtaining further evidence of the infection of dead teeth. During the past two years investigations in collaboration with Prof.

Blaisdell, in the Leland Stanford, Jr., University Laboratories of Pathology, have shown that fibrous marrow was present in the haversian bone at the root ends of pulpless teeth in *all* of the specimens examined. In all cases microscopic diagnosis of myelitis was established; and in many cases, diagnosis of osteomyelitis. The diagnosis was established in the *first* instance by the presence of fibrous marrow, a deviation from the normal marrow of the haversian bone of the jaw; the normal was conclusively shown to consist of both lymphoid and fatty marrow. The diagnosis in the *second* instance was established by absence of nuclei in the lacunae, irregular lamellae, differentiation in the staining qualities, and, in the more extreme cases, presence of structureless debris.

In my dental-college days I was taught that there were "lines of protoplasmic communication from the pericementum through the cementum into the dentine," just as Rhein was taught by Heitzmann in 1882. I was taught that the human tooth had two sources of nourishment, the dental pulp and the pericemental structure; but the best histology texts, recommended by the college authorities, failed to indicate that the college teachings were correct. The many openings through the apical end of the root, for the access of pulp tissue to the pulp chamber, is not a new discovery. Such openings, however, do not imply vitality in dentine after the tooth pulp has been destroyed. If apical tissue in and around the apical foramina were to survive pulp devitalization, atrophy of these filaments would set in. If they were to persist, they could not prevent access from the mouth (or combat development) of infection, in the tooth. Hence it is not out of place to reiterate that, even if the protoplasmic fluid that probably passes part way into the cementum could proceed to, or penetrate, the granular layer of Tomes, it would not be sufficient to maintain vitality in tooth dentine.

The statement that a "tooth remains a vital organ, so long as the cementum receives nourishment through the pericementum," is positively disproved by the fact that young cementum was deposited on a replanted tooth that had been boiled before replantation. A boiled tooth is certainly dead. It is not true that a pulpless tooth "is retained in the alveolus *because* life continues in a portion of the pericementum." The truth is, as has been pointed out frequently,

that all dead teeth, including those that have been boiled, are retained because of the deposition of cementum on their roots.

I have written to Dr. Box (and to Dr. Noyes who quoted him), on the matter affecting Dr. Box to which Dr. Rhein refers, but I have received no reply and I have been unable to ascertain just what Dr. Box claims to have discovered in the matter of the nutrition of devitalized teeth.

Since 1915 I have been pointing out emphatically that flat mouth is furthered, not by the removal of dead teeth, but rather by the retention of them. The low-grade inflammation (myelitis), that is present after dead teeth have been retained for some years, leads directly to flat mouth. When dead teeth are surgically removed early and thoroughly, loss of tissue does not result. *Alveolar process does regenerate*, providing infection and suppuration are not present. The early use of a proper plate does not imply that the alveolar process has ceased to function and that resorption is inevitable.

Scar tissue in oral mucosa does not become sensitive, if the underlying bone is normal and free from sharp edges.

Rhein states that the removal of the buccal plate of bone, for the purpose of extracting a tooth through this orifice, has been recommended from time to time for many years. At a meeting of the San Francisco District Dental Society, on October 25, 1920, Dean Millberry of the University of California College of Dentistry stated that, "regarding the priority of the buccal-plate operation, there are references in the literature to someone who had done this operation previous to 1914." A request for a more definite reference from Dean Millberry has brought no response. I have been unable to find any recorded reference to a buccal-plate operation, as a means of removing a dead tooth, prior to my own published description of such an operation. More definite information on this matter would be welcomed.

As I stated at the beginning of this reply to Rhein's comment, my position is difficult because I cannot say that I have examined teeth treated by Rhein, or by any of the "hundreds of dentists" who have been instructed by him in his technic. I have, nevertheless, examined dead teeth that were most carefully and skilfully treated precisely according to the technic publicly advocated by him and have found

all these teeth to be infected. This fact, however, will not surprise any experienced person who reads Rhein's claim that "it is questionable whether curettement of the average case requiring it cannot be done as effectively through the socket as by way of a buccal opening"—a statement that will shock everyone familiar with bone surgery and röentgenograms of dead teeth.

The three axioms mentioned by Rhein have been the cardinal principles of many men outside of Greater New York. Many other men, some of them in California, believed that they had accomplished precisely what is claimed by Rhein; but, time after time, they were proved to be in error. I have found nothing to convince me that Streptococcus viridans will not be found ensconced at the root ends of dead teeth "hermetically" sealed by Rhein, just as they occur at the root ends of dead teeth treated by less clever operators than he.

209 Post Street

A SUCCESS OR FAILURE IN BRIDGE-WORK: WHICH?[1]

CHARLES F. ASH

New York City

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I. INTRODUCTION

In this paper I summarize the clinical aspects of a case eight years after the dental service was rendered. I present also (a) a diagnostic view of the case involving systemic disturbances probably due to apical infections, showing the radiographic findings before and after treatment; and allude to (b) the mechanical restorations, including both fixed and removable bridges.

The patient was sixty-one years of age. The infection from which he had been suffering manifested itself in a distortion of vision in the left eye. Breathing through the nostrils was difficult and sometimes impossible, due to a condition resembling that of a heavy cold or acute hay fever.

The patient's oculist was at sea regarding local treatment, other than resting the eye by pasting paper over the left lens of the patient's glasses. The oculist believed that the trouble arose from infection. One rhinologist wanted to remove the inferior turbinates; another objected to surgical interference, but suggested that a dentist be consulted. The patient replied that he had been examined by his dentist

[1] Paper read before the First District Dental Society of the State of New York, at a meeting in New York City, March 1, 1920. See page liii of the Section on Proceedings of Dental and Stomatological Societies for a report of a discussion of this paper at that meeting by Drs. L. M. Waugh, Harold S. Vaughan, W. D. Tracy, Paul R. Stillman, N. T. Shields, H. W. Gillett, A. Berger, J. H. Tuttle, and H. E. S. Chayes, of New York City; Dr. T. W. Maves, of Minneapolis, Minn.; and Dr. Ash.

and his teeth were considered "O.K." The rhinologist then said: "What you need is a new dentist, for I can see that there are infections in your mouth."

II. CONDITION AND TREATMENT OF THE TEETH

Upon examination I found all the teeth present in the *upper jaw* except the right upper second bicuspid and left upper third molar, several having been crowned. The buccal and labial surfaces of the upper gums showed six fistulae, with pus oozing from every one. In the *lower jaw* all the teeth were in place except the first molar on each side.

Teeth in the upper jaw. Physical and x-ray examinations showed that there was only one vital tooth in the upper jaw, namely, the left lateral.

The right upper first and second molars, left upper cuspid and second bicuspid, being hopelessly involved, were immediately extracted and the sockets thoroughly curetted.

The left upper first and second molars showed imperfect root fillings but no rarefaction. The left upper first bicuspid showed an imperfect root filling with slight rarefaction, and a piece of metal imbedded in the upper third of the palatal root. The left upper lateral showed no root filling and no apical rarefaction.

The two upper centrals bore pivots which had been put on by Dr. Dwinelle forty years before, the left central having a fairly good root filling of gutta-percha and the right central having been filled with cotton, and showing decided areas of rarefaction.

The right upper lateral and cuspid showed no root filling and had definite areas of rarefaction. (Upon opening these teeth, the cuspid was found to contain a dry gangrenous pulp, and the lateral was suppurative.) The right upper first bicuspid had no root filling and showed no infection, though the pulp was partly decomposed. The right upper third molar had imperfect root fillings, with a heavy metal post cemented in one root.

The left upper first molar roots having been filled for some years (although incompletely) and showing no apical disturbance, it was decided not to interfere with these roots. The left upper second mo-

lar was opened and a piece of steel broach removed from the anterior buccal root; the disto-buccal root could not be opened. The left upper lateral was devitalized, treated with "S. and P.," and the root filled with gutta-percha. The upper third of the root, however, shows only a slight film of chloro-percha.

The roots of all the other teeth in the upper jaw were opened, treated and refilled, although I had great difficulty in reaching the apex of the palatal root of the left upper first bicuspid, where the piece of metal was imbedded. The apex of this root was amputated, as were also the apices of the left central and the right central, lateral and cuspid, and over these last four extensive curettement was done, the necrotic area involving the floor of the nasal cavity and the front wall of the right antrum.

Individual crowns were made for the left central, right central, right lateral and cuspid. An assembled abutment bridge, after the pattern designed by Dr. Theodore Brown, of Brooklyn, was made for the right side, using the first bicuspid and second molar as abutments, and supplying two teeth on the removable saddle. On the left side a split-bar removable bridge was inserted, using the lateral, first bicuspid and first molar as abutments, and supplying the cuspid and second bicuspid. For the left second molar, a separate cast gold crown was made.

Teeth in the lower jaw. In the lower jaw all the teeth present were vital except the left second molar. The radiogram of this tooth showed a rarefied area around the apex and little or no root filling. Upon opening the roots of this tooth for treatment, however, we found the roots partly filled with various "odds and ends," such as cotton, bits of what-seemed-like-gutta-percha, and some very hard cement. I was unable to open the mesial roots to the apex, but did succeed in opening and filling the distal canal to the apex.

The second bicuspid was devitalized and filled with gutta-percha. A dowel crown was made for the bicuspid and a cast-gold crown on a platinum shell was made for the molar, extending the mesial side of the molar beyond the normal contour sufficiently to secure contact with the second bicuspid. This was resorted to as the simplest method of filling the space and completing the occlusion, until it could be observed what might happen in the region surrounding the apex of the second molar.

On the right lower, the second bicuspid and second molar were devitalized and filled, and a fixed bridge inserted with two crowns and one dummy.

III. ILLUSTRATIONS AND FURTHER COMMENT

The initial, and final conditions after eight years, are shown in the accompanying illustrations (*plates 1–5; figs. 1–38*).

The clearing up of the focal infections was, of course, of the first and most immediate importance. Only slightly secondary to that, however, was the importance of endeavoring to secure satisfactory occlusion for this patient, which he had not had except in the molar region since his early childhood. A glance at *fig. 23* will show that there was contact only in the molar region; and that there was a large gap between the upper and lower bicuspids.

The patient was able to close his lips only with an effort. In order to close the bite, therefore, I resorted to grinding the upper molars until there was contact between the left upper second bicuspid and the left lower first bicuspid (*fig. 25*). I then continued to grind the upper molars and also the left upper second bicuspid, the result of which was to throw the mandible forward, the progress of this operation being shown in *fig. 26*. *Fig. 28* shows the final position of the right upper first bicuspid, the buccal cusp of which is resting between the lower first and second bicuspids. Compare this with *fig. 23*.

By bringing the mandible forward in this way, the contour of the mouth appears (in the final result) as though the upper jaw had been retracted. The present contour of the face is shown in *figs. 37* and *38*. The present contour and occlusion of the teeth are shown in *figs. 29–34*. *Figs. 35 and 36* show the bridge in the mouth.

115 Broadway

PLATES 1–5

(ASH: A SUCCESS OR FAILURE IN BRIDGE-WORK: WHICH?)

PLATE 1

FIG. 1. Original condition of the left upper molars, bicuspids and cuspid. The second bicuspid and cuspid were extracted later.

FIG. 2. Original condition of upper laterals and centrals.

FIG. 3. Condition of the left upper lateral and central after treatment and filling. Note the thin filling of chloro-percha in the apical third of the lateral.

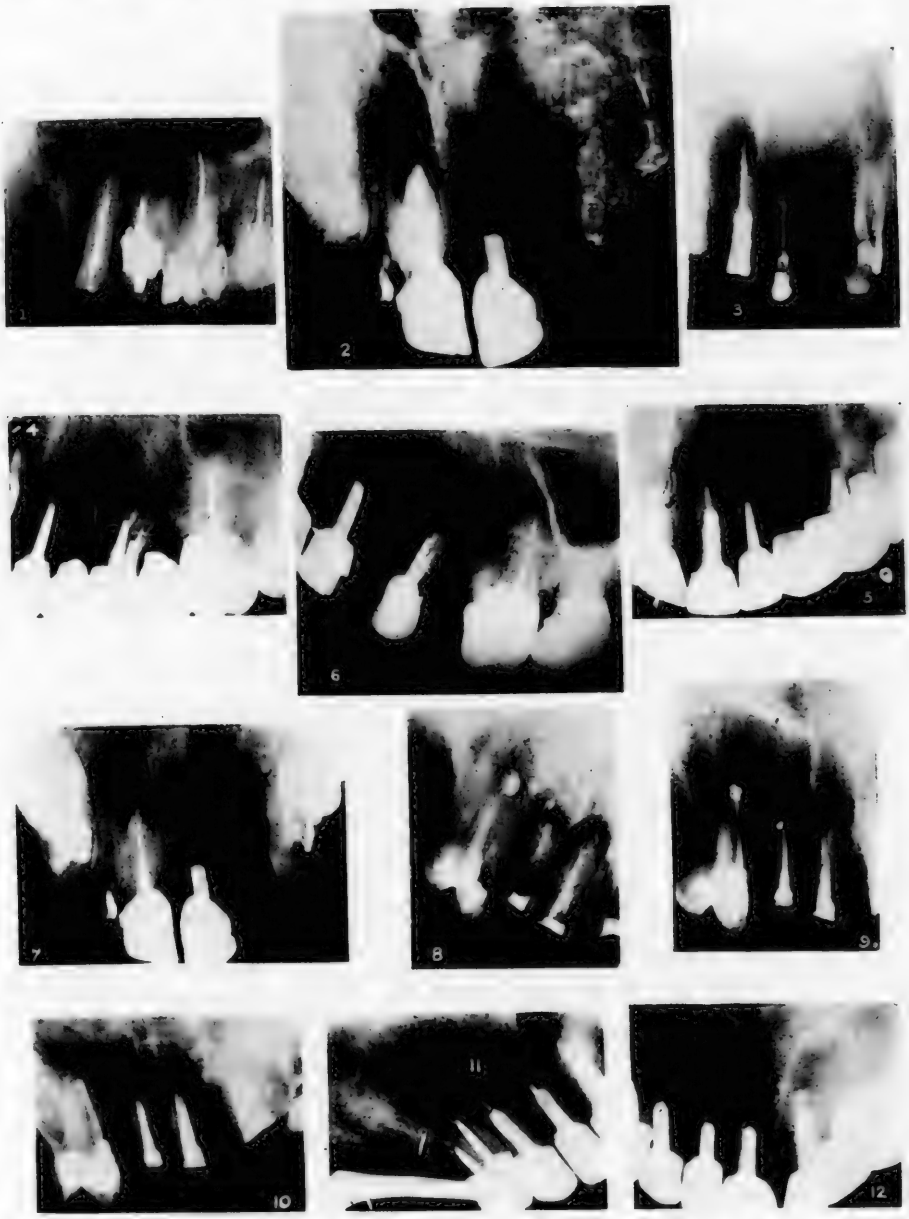
FIGS. 4, 5 AND 6. Present condition of the left upper central, lateral, first bicuspid, and first and second molars. Note the healthy conditions under the dummies where new bone has formed, especially on the site of the extracted cuspid. Compare *fig. 1* with *figs. 4* and *6*. Note in *fig. 4* the slight thickening of the pericementum around the lateral, due, probably, to trauma.

FIG. 7. Original condition of the right upper central and lateral.

FIGS. 8 AND 9. Results of the treatment and filling of the right upper central, lateral, and cuspid. There was a perforation in the central, near the apex.

FIG. 10. Conditions immediately after amputation and curettement of the right upper central, lateral, and cuspid. This figure also illustrates the necessity for taking pictures at a proper angle to avoid false diagnosis. Although all of these teeth were filled through the apex and then amputated straight across the apices, *fig. 10* makes the root fillings appear short of being flush with the amputation surfaces.

FIGS. 11 AND 12. Present condition of the teeth shown in *figs. 8, 9* and *10*. Note, in *fig. 11*, the good condition of the bone under the saddle; also the absence of pyorrhea pockets. There is a slight degree of rarefaction over the cuspid due to the presence of foreign substance (probably gutta-percha), left after curettement.



(Ash: Success or Failure in Bridge-Work: Which?)

PLATE 2

FIG. 13. Original condition of the upper bicuspids and molars on the right side.

FIG. 14. Second molar (*fig. 13*) before treatment.

FIG. 15. Second molar (*fig. 14*) during treatment.

FIG. 16. Second molar (*fig. 15*) after treatment.

FIG. 17. Present condition of the second molar (*fig. 14*). Note the healthy bone and absence of pyorrhea pockets.

FIG. 18. Slight rarefaction around the apex of the left lower second molar.

FIG. 19. Condition of the tooth shown in *fig. 18*, after treatment with sodium-potassium and filling. Note the increased rarefaction at the apex.

FIG. 20. Present condition of the left lower second molar (*figs. 18* and *19*). Note the healthy bone and absence of pyorrhea pockets in the interproximal space. Rarefaction persists at the apex.

FIG. 21. Right lower second molar and bicuspid in the process of filling and treatment.

FIG. 22. Present condition of the right lower second molar (*fig. 21*). Note the healthy bone and absence of pyorrhea pockets.

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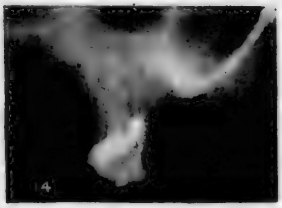
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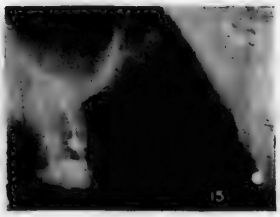
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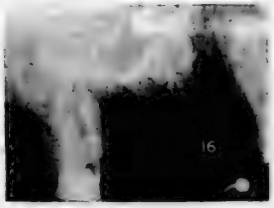
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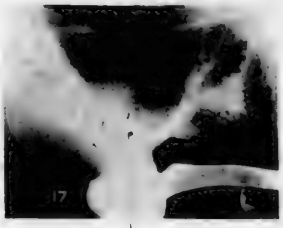
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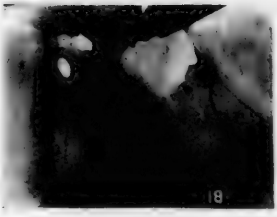
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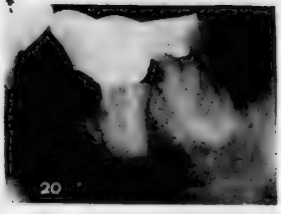
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(Ash: Success or Failure in Bridge-Work: Which?)

PLATE 3

FIG. 23. Cast showing the condition of the right side, after the extraction of the first and second molars. Note the position of the right upper first bicuspid as related to the two lower bicuspids. Then compare with *figs. 26* and *28*.

FIG. 24. Cast showing the front view of the mouth, after the removal of the old crowns.

FIG. 25. Cast showing the condition of the left side, after the extraction of the left upper cuspid and left upper second bicuspid. Compare the position of the lateral and bicuspid, in this case, with the position of the lateral and bicuspid in *fig. 28*.

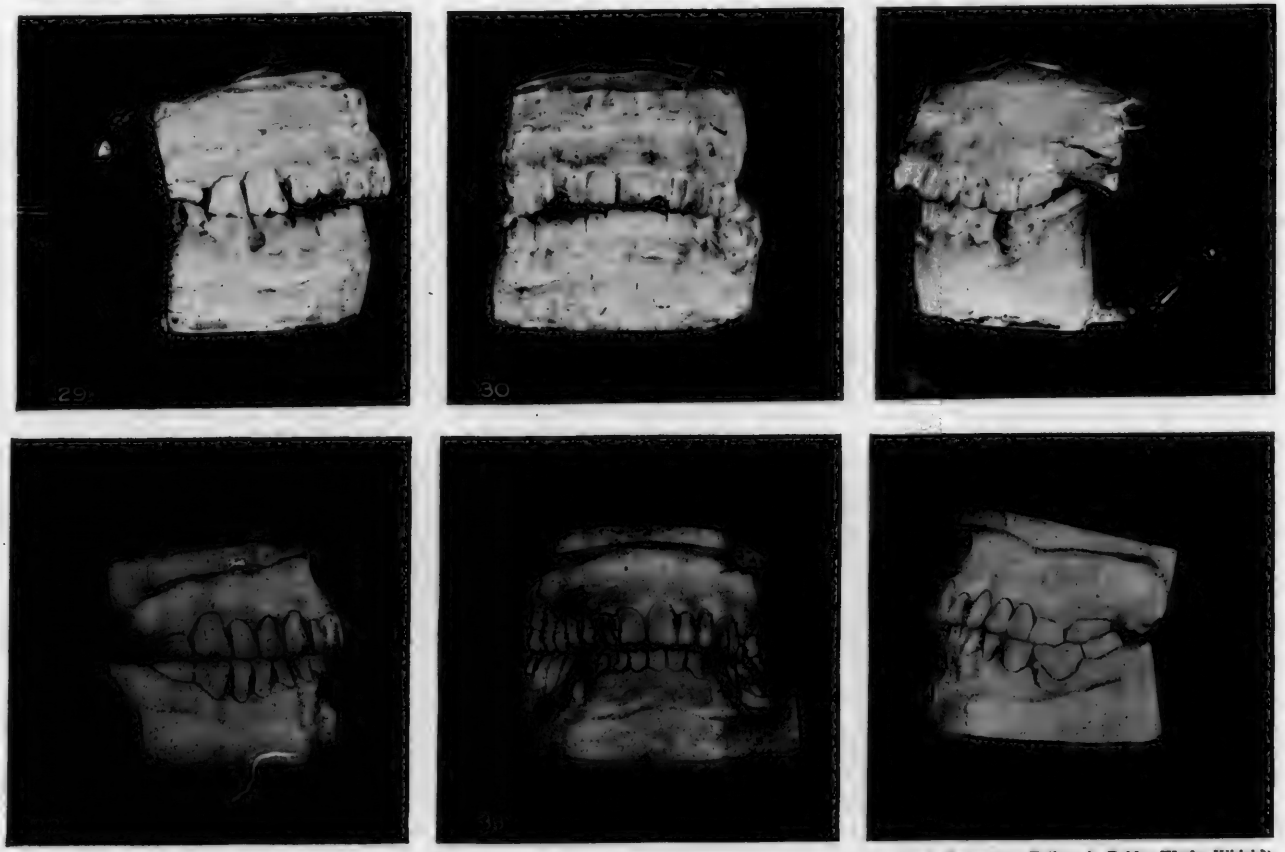
FIGS. 26 AND 27. Casts showing the changes in occlusion that were brought about by grinding the teeth.

FIG. 28. Cast showing the final relation of the right upper bicuspid to the two lower bicuspids.

(Ash: Success or Failure in Bridge-Work: Which?)

PLATE 4

FIGS. 29 AND 32. Casts showing the right side of the mouth, before and after treatment.
FIGS. 30 AND 33. Casts showing the front view of the mouth, before and after treatment.
FIGS. 31 AND 34. Casts showing the left side of the mouth, before and after treatment.



(Ash: Success or Failure in Bridge-Work: Which?)

PLATE 5

FIGS. 35, 36, 37 AND 38. Photographs of the patient, showing the completed case in the mouth.

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THE ORIGIN AND EVOLUTION OF THE HUMAN DENTITION

A Palaeontological Review

(*Continued*)

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PART IV. THE DENTITION OF THE HIGHER PRIMATES AND THEIR RELATIONSHIPS WITH MAN[1]

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[1] Parts I, II, and III, of this review, were published successively in the March, June, and September numbers of this volume, beginning, respectively, at pages 89, 215, and 357. It had been intended to publish the remainder of the review in this issue, but it has been found expedient to divide the concluding section into Part IV (in this number) and Part V (to be published in the issue for March, 1921). Part V will present a discussion of the later stages in the evolution of human dentition, and also a general summary of the entire review, with a list of all the references to the literature in each of the five parts.—(Ed.)

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1. ORIGIN AND RISE OF THE "OLD WORLD" MONKEYS (SERIES CATARRHINÆ, FAMILY CERCOPITHECIDÆ)

INTRODUCTION: PHYLOGENETIC RELATIONSHIPS OF THE TARSIOID, PLATYRRHINE AND CATARRHINE SERIES

In Part II of this review we have seen that, so far as is known, the true primates of the Lower Eocene were already thoroughly arboricolous in habit, as is shown by the quadrumanous form of their extremities; and that consequently their dentition was adapted to the food that may be found in trees, such as fruits, leaves, insects, and the eggs and young of small birds. The existing tree-shrews, or Tupaiidæ, and their Paleocene relatives the Plesiadapidæ, as we saw, are very probably more or less specialized side branches from the very base of the primate stem; indeed in many respects they are intermediate between the primates and some still more primitive but as yet undiscovered clawed, insectivorous, ancestral, placental mammals of the Paleocene and Upper Cretaceous epochs. Whether or not the Menotyphla, comprising the Plesiadapidæ, Tupaiidæ and Macroscelididæ, are to be included within the order Primates, seems, from present evidence, to be largely a matter of definition. The oldest known Menotyphla, the Plesiadapidæ, were apparently excluded from direct ancestry to the typical primates by the specialized characters of their front teeth, while, on the other hand, their extremities, so far as known, had not yet attained such a high grade of adaptation to grasping the limbs of trees as is exhibited by the oldest typical primates of the families Notharctidæ and Tarsiidæ.

The last two families are first definitely known, or generally admitted to be present, in the Lower Eocene of North America and of Europe, but they may have been partly differentiated in the Paleo-

cene both from each other and from the Menotyphla, the Condylarthra and other placental orders.

The Notharctidæ, it was shown, were a comparatively conservative and slowly evolving group. They had the remarkably primitive dental formula of $I\frac{2}{2}$ $C\frac{1}{1}$ $P\frac{4}{4}$ $M\frac{3}{3}$, and at first their dentition differed but little from that of the most primitive families (Mioclænidæ, Hyopsodontidæ) of the contemporary Condylarthra, or "proto-ungulates." The earliest species of Notharctidæ, and indeed of all other primates, had tritubercular upper molars and well marked interdental spaces; but, as we pass upward through ascending geological levels, the upper molars gradually become more quadrangular by the outgrowth of the postero-internal (disto-lingual) cusp. This arises either from the cingulum (Adapidæ, Tarsiidæ), or by budding from the main internal cusp, or "protocone" (Notharctidæ). The Notharctidæ, as well as their relatives, the European Adapidæ, retained a relatively primitive type of skull structure, with unreduced muzzle, orbits of moderate size, and braincase not greaty expanded.

The Adapidæ were in a distinctly sub-lemuroid stage of evolution, and some of them transmitted many of their primitive dental and cranial characters to the modern Lemuridæ and related families, all of which, however, have progressed in the further enlargement of the brain case and in the peculiar specialization of the lower incisors and canines.

The Notharctidæ increased gradually in size until the close of the Middle Eocene, when the largest of them was nearly as large as a modern howler monkey (*Alouatta*). The family may perhaps be represented in the Upper Eocene by a fragment of a lower jaw, the type of *Notharctus* (?) *uintensis*, the last known member of the family.

As was suggested by Leidy and by Wortman, it is possible that the Notharctidæ gave rise to the "New World" monkeys, or Platyrrhinæ; but, after considering the available evidence, it was suggested that the Platyrrhinæ may rather have been derived from some genera of Eocene or Paleocene primates that combined the more primitive front teeth of the Notharctidæ with the more advanced skull characters of the Tarsiidæ.

The known Eocene Tarsiidæ, as described in Part III, are precociously specialized forms, which rapidly develop many of the higher

characters of an expanded braincase, large orbits, a shortened face, large auditory bullæ, etc. But most of them yielded too readily to the tendency to acquire enlarged and specialized lower front teeth and many also seem to have overdone, as it were, the progressive

FIG. 213. *Cebus capucinus*, REPRESENTING THE PLATYRRHINÆ. AFTER ELLIOT

skull characters named above. Thus many of them remove themselves from the lines of ascent leading respectively to the New World and to the Old World series of higher primates. Some of the tarsioids by eliminating the first premolar of the original four, both in the upper

and lower jaws, reduced the dental formula to $I\frac{2}{2}\ C\frac{1}{1}\ P\frac{3}{3}\ M\frac{3}{3}$, as in the Platyrrhinæ, while some others went further and eliminated also the second upper and lower premolars, thus reducing the formula to $I\frac{2}{2}\ C\frac{1}{1}\ P\frac{2}{2}\ M\frac{3}{3}$ as in the Catarrhinæ.

The later Eocene European tarsioids (*Necrolemur*, *Microchœrus*) have advanced toward the pithecoid grade of organization in the

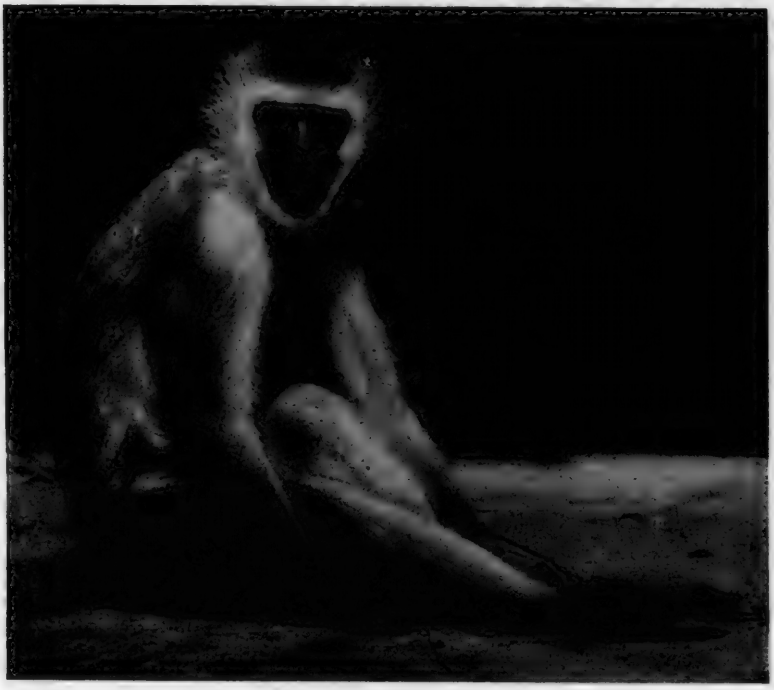


FIG. 214. *Lasiopyga* (*Cercopithecus*) *pygerythrus*, REPRESENTING THE CATARRHINÆ. AFTER ELLIOT

construction of their orbits, auditory region, and dental arch, and they have likewise succeeded in differentiating the quadrate first and second upper molar crowns into subequal anterior and posterior moieties, without, however, obliterating the tritubercular ground plan; while the crown patterns of their lower molars are more or less transitional between the more primitive VV-shaped tuberculosec-

torial and the more advanced five-cusped bunodont type of the stem Catarrhinæ. The crown patterns of the third and fourth upper and lower premolars of *Microchœrus erinaceus* are likewise more or less intermediate between those of lower, more primitive, tarsioids and those of *Oreopithecus*, *Parapithecus* and other relatively primitive Catarrhinæ to be described below. It will also be recalled that in *Necrolemur* and *Microchœrus*, the angular process of the mandible becomes expanded into a form which foreshadows the still more expanded condition of this part in the "Old World" group.

The phylogenetic significance of these pro-pithecoid characters attained by later Eocene tarsioids of Europe, becomes greater in consideration of the fact that their modern relative, *Tarsius*, possesses many clear marks of remote kinship with both main divisions of the higher primates, so that some authors have even proposed to brigade *Tarsius* and its relatives with the Platyrrhinæ and the Catarrhinæ in a single suborder.

Although the Platyrrhinæ and the Catarrhinæ may have been derived from Eocene primates that might fall under a broad definition of the Tarsioidea, it is not probable that they both started from the same genus of tarsioids or even from closely allied genera. In view of the remarkable constancy of the cranial, dental, and other characters that separate the Platyrrhinæ and the Catarrhinæ, and also of the marked differences in the jaws and dentition between the oldest members of each series, it seems far more probable that the New World series has been derived from some relatively primitive American tarsioid genus having the dental formula, $I\frac{2}{2}\ C\frac{1}{1}\ P\frac{3}{3}\ M\frac{3}{3}$; and that the Old World group was derived from a much more advanced and later Eurasiatic tarsioid genus having the dental formula, $I\frac{2}{2}\ C\frac{1}{1}\ P\frac{2}{2}\ M\frac{3}{3}$, and many but not all dental and cranial characters in common with *Necrolemur* and *Microchœrus*.

PARAPITHECUS, OF THE LOWER OLIGOCENE OF EGYPT, AND THE TRANSITION FROM THE TARSIOID TO THE CATARRHINE GRADE OF ORGANIZATION

That the higher primates have been derived from Tarsioids of some sort, although not necessarily from any known genera, has also been maintained on palæontological grounds by Schlosser, who in 1911

described and figured the mandible of *Parapithecus fraasi*, a small primate from the Lower Oligocene of Egypt. The dental formula of this highly important genus was provisionally given by Schlosser (*op. cit.*, p. 58) as $I\frac{1}{1}$ $C\frac{1}{1}$ $P\frac{2}{2}$ $M\frac{3}{3}$, but he noted that the identification of the second lower tooth as a canine was doubtful. The anthropologist Schwalbe (1915, pp. 234, 235), after examining a cast of this specimen, rightly concluded that the second tooth was the lateral incisor and that the dental formula was $I\frac{2}{2}$ $C\frac{1}{1}$ $P\frac{2}{2}$ $M\frac{3}{3}$, as in the other "Old

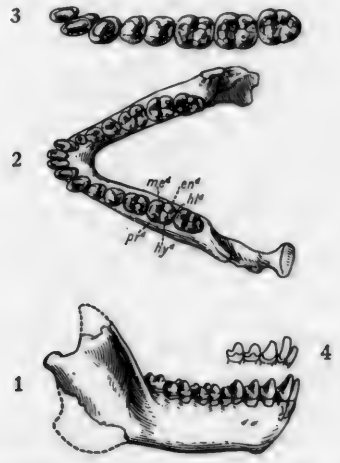


FIG. 215. *Parapithecus fraasi*. LOWER OLIGOCENE, FAYÛM, EGYPT

1, 2.—Lower jaw. × 1. Modified from Schlosser.
3.—Lower teeth, crown view. × 3/2. After Schlosser.
4.—Medial view of incisors, canines, and premolars. × 1. After Werth.

World" primates. The same interpretation was independently reached and defended in detail in my "Studies on the evolution of the primates" (1916, p. 281). In 1919 E. Werth published his valuable paper entitled "*Parapithecus*, ein primitiver Menschenaffe," in which he gives (p. 329) a medial view of the lower incisors, canine, and premolars of this animal, which should set at rest all doubt as to the correctness of the dental formula as interpreted by Schwalbe, Werth, and the present writer.

Parapithecus is by far the most primitive of all known Old World monkeys and apes, and with regard to its known characters it may well be regarded as standing in or quite near to the line of ascent leading to the anthropoid apes and eventually to man. Unlike most or all of the known tarsioids it does not appear to be excluded from this important position by any pronounced aberrant specializations of the dentition, except possibly the too conic form of the lower molar cusps. *Parapithecus* is the smallest of all known Catarrhinæ, its interesting size-relations being suggested in the following comparative measurements:

	SUBORDER TARSIOIDEA		SUBORDER ANTHROPOIDEA, SERIES CATARRHINÆ			
	Necrolemur antiquus, Upper Eocene, Europe	*Microcherus erinaceus*, Upper Eocene, Europe	*Parapithecus fraasi*, Lower Oligocene, Egypt	*Propliopithecus haeckeli*, Lower Oligocene, Egypt	*Pliopithecus antiquus*, Pliocene, Europe	*Hylobates* (*Symphalangus*) *syndactylus*, Recent
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Length of whole tooth row (I_1–M_3)	16	—	25	30	43	51
Length of three lower molars.	8	11	12.5	15	20	24
Length from mandibular condyle to tip of lower front teeth	28	—	36.5	—	—	86

The opposite rami of the lower jaw of *Parapithecus* converged rapidly toward the narrow chin, which sloped sharply backward. This configuration is partly correlated with the small size of the lower canines, which had not yet become enlarged as they are in later anthropoids. The marked divergence posteriorly of the mandibular rami and the relative anteroposterior shortening of the jaw indicate that the skull was correspondingly wide across the glenoid surfaces, this character being frequently correlated with a transverse expansion of the brain. The absence of p_1, p_2 and the consequent reduction of the lower premolars to two on each side imply an early shortening of the face, perhaps not unlike that seen in *Necrolemur*. The relatively low position of the mandibular condyle, together with the backward inclination of the whole ascending ramus and the relative shallowness

of the horizontal ramus, indicate that the face was less bent down upon the cranium than it is in the higher apes.

As to the probable nature of the food of *Parapithecus*: the small size and lack of laniary modification of the canines, and the blunt non-sectorial form of the premolars and molars, would exclude specialized carnivorous habits, while the gently procumbent incisors and low-cusped cheek teeth seem to indicate a mixed diet, possibly of insects, fruits, bird eggs, and small reptiles. From the pointed form of the lower dental arch it is legitimate to infer that the upper dental arch was also convergent in front and, from this fact and other considerations, it is apparent that the upper canines were not laniariform. The two upper premolars must have been more or less bicuspid in order to articulate properly with the lower premolars; while from the elongation of the first and second lower molars, and from the arrangement of their five cusps, it is perfectly safe to infer that the first and second upper molars were more or less quadrate in form, with well-developed posterointernal cusps or hypocones. The five-cusped bunodont lower molars had already advanced far from the primitive primate types represented in the Lower Eocene tarsioids and lemuroids. The trigonid is now depressed to the level of the talonid, the paraconid has been lost, and the primitive V-shaped cusps have become low and conical and have almost lost their crests. The potentially bicuspid premolars are widely unlike the molars, whereas in more primitive mammals the contrast between the posterior premolars and the molars is not so great

In view of the foregoing considerations, taken in connection with the fact that there are many special resemblances between the lower dentition of *Parapithecus* and that of the contemporary *Propliopithecus*, the oldest known true anthropoid, there is good reason to infer that the skull of *Parapithecus*, when discovered, will be found to exhibit a mixture of characters, some recalling tarsioid conditions and others foreshadowing the catarrhine or primitive anthropoid grade of organization, but none of extreme or aberrant specialization.

APIDIUM, OF THE LOWER OLIGOCENE OF EGYPT, A STRUCTURAL ANCESTOR OF THE CERCOPITHECOID TYPE OF DENTITION

This interesting fragment of a small lower jaw, containing the fourth premolar and the three lower molars, was found in the Lower Oligocene of Egypt and described in 1908 by Professor Osborn, who showed that the animal differed from the small contemporary artiodactyls, especially in the form of its premolars. He noted that it differed also from all hitherto described genera of Primates and

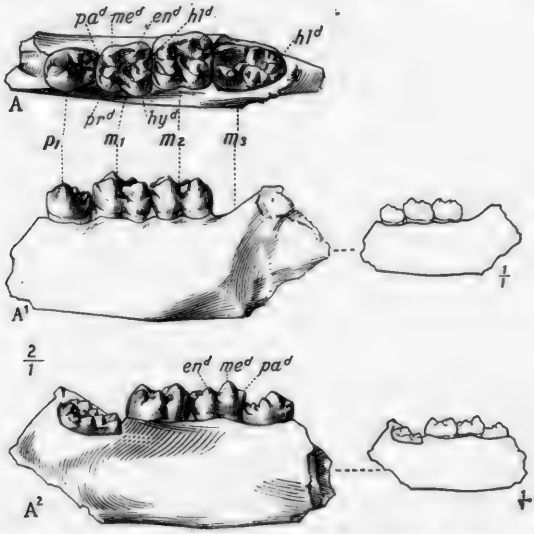


FIG. 216. *Apidium phiomensis*. LOWER OLIGOCENE, FAYÛM, EGYPT. AFTER OSBORN

Type, Amer. Mus., no. 13,370. A, superior; A^1, lateral; A^2, medial view. Outline figures, × 1; shaded figures, × 2.

stated that its ordinal position would remain uncertain until the front teeth are discovered. Schlosser, in his memoir on the Lower Oligocene mammals of the Fayûm (1911, pp. 67–68), inclined to the opinion that *Apidium* was a primate and possibly a forerunner of the Cercopithecidæ. This determination is somewhat strengthened by the following considerations.

(1) As compared with the contemporary *Parapithecus*, which is admittedly a primate, *Apidium* presents a fundamental agreement in

the ground plan of its fourth lower premolar and three lower molars. In both cases the fourth lower premolars are potentially more or less bicuspid and sharply differentiated from the molars; the molars are elongate anteroposteriorly and bear five principal subconical cusps, arranged in two pairs, with a median hypoconulid. These resemblances alone would not be sufficient to demonstrate an ordinal affinity of *Apidium* with *Parapithecus*, but they gain in value when considered in connection with other evidence.

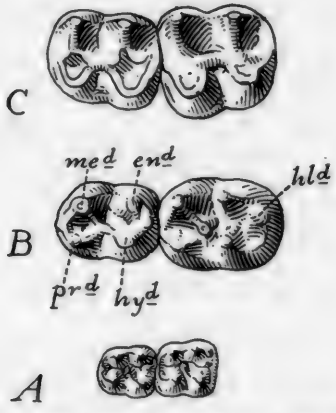


FIG. 217. COMPARATIVE SERIES: FIRST AND SECOND LOWER MOLARS OF *Apidium*, *Oreopithecus*, *Dolichopithecus*.

A. *Apidium phiomensis*. × 2. After Osborn.
B. *Oreopithecus bamboli*. × 3/2. From a cast.
C. *Dolichopithecus ruscinensis*. × 3/2. From a cast.

(2) From an inspection of Figs. 216 and 217, it will be evident that the lower teeth of *Apidium*, so far as known, have the same ground plan as do those of *Oreopithecus* (a peculiar catarrhine ape from the Lower Miocene of Italy), but that they are far more primitive and are nearer to a still older, more tarsioid stage. Thus in *Apidium*, while p_4 is at most incipiently bicuspid, in *Oreopithecus* the corresponding tooth is fully bicuspid and has the posterior cingulum and talonid fossa further developed. The lower molars of *Apidium* retain much that is reminiscent of a lower primate stage, the talonids of m_1, m_2 being notably wider than the trigonids. On the other hand they

foreshadow the conditions in *Oreopithecus* in the facts (a) that the molars are elongate anteroposteriorly, (b) that the third molar is longer than the second, and (c) that the crista obliqua bears a new cusp at its anterior end immediately behind the posterior slope of the talonid. The hypoconulids, unusually prominent, at least on m_1, m_3 in *Apidium*, are well developed in *Oreopithecus*.

(3) The lower molars of *Apidium* remotely resemble those of *Cebochœrus*, a relatively primitive member of the Suidæ from the Eocene of Europe, but Schlosser (*op. cit.*, p. 68) pointed out that this general resemblance does not extend to the more significant details and that *Apidium* differs widely from *Cebochœrus* and other early artiodactyls which have compressed lower premolars. Although the status of *Apidium* as a primate is not fully established, no Eocene artiodactyl, hyracoid, or other mammal with which I have compared it, affords so favorable a comparison of the patterns of p_4, m_1, m_2, m_3, with those of *Oreopithecus*. We have also seen that, so far as known, the lower teeth of *Apidium* are more or less intermediate in pattern between an Upper Eocene, *Necrolemur*-like stage and a Lower Miocene cercopithecoid stage.

(4) From the relatively high stage of evolution attained by *Oreopithecus* in the Lower Miocene, it is to be expected that in the Lower Oligocene the cercopithecoid group had already begun to separate from the related anthropoid stock. *Apidium*, so far as known, appears to conform with reasonable expectations of what such a Lower Oligocene stage should be like.

(5) That ancestors or relatives of the later Cercopithecidæ were present in the Lower Oligocene of Egypt is also extremely probable from the fact that the American Museum expedition in 1907 discovered there a frontal portion of a skull which resembles closely the corresponding part of some of the smaller Cercopithecinæ.

OREOPITHECUS, A PRIMITIVE CERCOPITHECOID OF THE LOWER MIOCENE OF ITALY

In Lower Miocene (Vindobonian) times there was a more or less continuous tract of land extending from northern Italy eastward to and beyond India. Primitive anthropoid apes, cercopithecoid mon-

keys and other mammals, all originating, it is believed, in Asia, spread westward and are found in Miocene and Pliocene deposits of Europe and Asia (Osborn, 1910, p. 255). The genus *Oreopithecus*, already mentioned as occurring in the Lower Miocene of Italy, differs in so many details of its dentition from the typical Cercopithecidæ that it was set apart as a distinct family, "Oreopithecidæ," by Schwalbe (1915), who has described the jaws and dentition of this animal in great detail. Its dentition on the whole appears to be more primitive than that of the Cercopithecidæ in the fact that the molars, although having the principal cusps arranged in pairs, do not have the opposite cusps connected by high transverse crests. The upper molars are quadrate with four principal conical cusps. They differ from the molars of anthropoids especially in having a prominent crest running obliquely from the base of the metacone forward and inward toward the protocone, and meeting another oblique crest running forward and outward from the hypocone. The mode of derivation of this rather peculiar arrangement is unknown. The upper canines are not enlarged as they are in most other monkeys and apes, but end in a bluntly conical tip, which does not project below the level of the premolars. Partly in correlation with the lack of a tusk-like specialization of the canines the upper dental arch is convergent in front. As noted above (p. 618), the lower molars differ from those of the more typical Cercopithecidæ in having a rather prominent cuspule located at the anterior end of the crista obliqua of the hypoconid. On the whole the affinities of *Oreopithecus* seem to be clearly with the Cercopithecidæ rather than with the anthropoid apes, and its peculiar generic characters do not seem sufficiently important to necessitate placing it apart in a distinct family.

THE SEMNOPITHECINE MONKEYS OF MIOCENE AND LATER EPOCHS

The semnopithecine monkeys (including the well-known "Entellus" monkey of India and many other Asiatic and African forms) represent an herbivorous specialization of the primitive catarrhine stock. As is well known, the cœcum is enormously developed for the digestion of vegetable food, while the two-crested molars, which in the Lower Pliocene genus, *Dolichopithecus*, were remarkably like those of

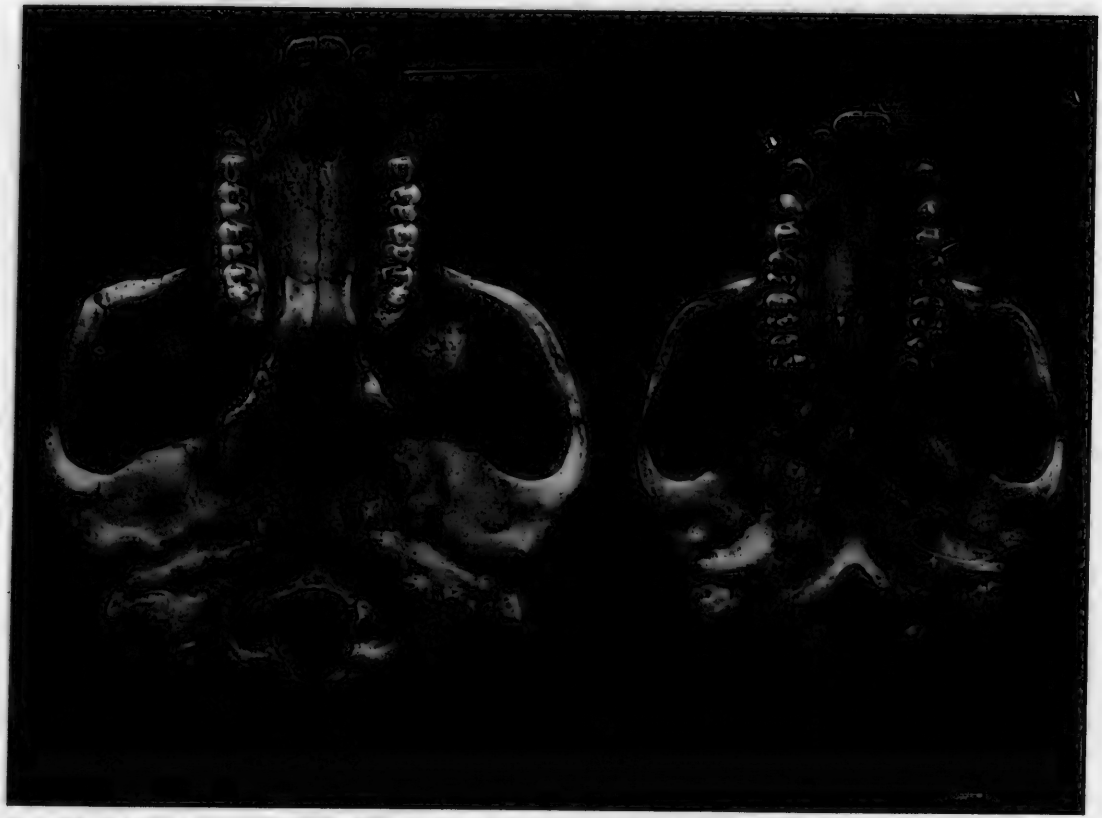


FIG. 218. *Colobus brunneus.* UNDER SIDE OF MALE (LEFT) AND FEMALE SKULLS SHOWING WIDE DIFFERENCES IN DENTAL ARCHES, ASSOCIATED WITH DIFFERENCES IN FORM OF CANINES

Courtesy of Dr. J. A. Allen and Mr. H. Lang, American Museum of Natural History.

tapirs and kangaroos, are also adapted for the cutting of leaves and tender shoots. The laniariform canines, which have doubtless become specialized from the smaller canines of more ancient primates, are useful in fighting and possibly in piercing the tough rinds of large fruits.

The Semnopithecinæ exhibit some interesting variations in the length and proportions of the jaws and cranium, and in the form of the upper dental arch. The most primitive genera, *Dolichopithecus*, *Mesopithecus*, had a rather large muzzle and a comparatively low braincase. In some species of *Semnopithecus* (*Pygathrix*) and *Colobus* (*fig. 218*), the face and the cranium both become short, with consequent anteroposterior shortening of the dental arches, molars and lower jaw. The upper dental arch in *Colobus* males diverges anteriorly in correlation with the tusk-like form of the canines, while in females with small canines the dental arch becomes convergent in front. In *Nasalis* (*fig. 222*) there has apparently been a marked oblique downward growth of the upper jaw and a secondary anteroposterior elongation of the molars. In *Rhinopithecus* (*fig. 220*) the lower jaw becomes very stout and deep and acquires a sort of anthropoid appearance.

THE CERCOPITHECINE MONKEYS

This division of the family Cercopithecidæ first appears in the Lower Pliocene of India, from which isolated molars not differing greatly from those of modern cercopithecine monkeys have been described by Lydekker and by Pilgrim (1915). The primitive cercopithecine monkeys (macaques, baboons, and related genera) apparently had a rather short face. There are many species still existing, the skulls of which may be arranged in a structural series beginning with the short-faced macaques (*fig. 227*) and culminating in the mandril among the dog-faced baboons (*fig. 229*). The molars share a little of this anteroposterior elongation (*fig. 229*) but not nearly so much as in many lines of long-faced ungulates.

In another direction we may pass by way of the Gibraltar ape (*Macacus inuus*) to the deep-faced gelada baboon (*Theropithecus*, *fig. 228*). There is a group of African genera centered around *Cercocebus*,

FIG. 219. *Pygathrix (Semnopithecus) entellus.* × 4/5

FIG. 220. *Rhinopithecus bieti.* × 4/5

FIGS. 219 to 226, INCLUSIVE. COMPARATIVE SERIES: SKULLS OF SEMNOPITHECINÆ. SKULLS AFTER ELLIOT, REARRANGED

FIG. 221. *Colobus verus.* × 4/5

FIG. 222. *Nasalis larvatus.* × 4/5

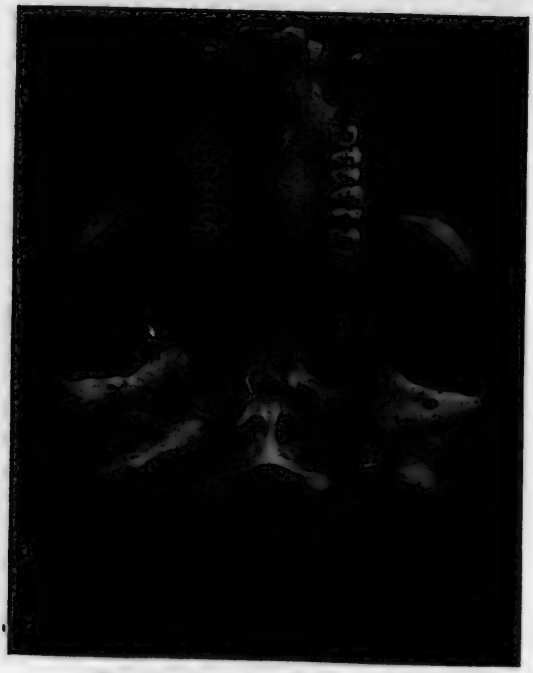


FIG. 223. *Pygathrix entellus.* × 4/5

FIG. 224. *Rhinopithecus roxellanæ.* × 4/5

FIG. 225. *Colobus verus.* × 4/5

FIG. 226. *Nasalis larvatus.* × 4/5

FIG. 227. *Pithecus brevicaudus.* × 4/5

FIG. 228. *Theropithecus obscurus.* × 3/4

FIGS. 227 to 229, INCLUSIVE. COMPARATIVE SERIES: SKULLS OF CERCOPITHECINÆ. SKULLS AFTER ELLIOT, REARRANGED

FIG. 229. *Papio sphinx.* × 3/4

which likewise exhibits some interesting variations in head form. One of them (*Erythrocebus*) has a relatively long cranium and face, while a related genus, *Miopithecus*, has an expanded braincase and short mandible. The former is a plains-living quadrupedal monkey, while the latter lives in the trees.

Notwithstanding the variations in length of face among the Cercopithecidæ, the first and second upper and lower molars always present two distinct and subequal anterior and posterior moieties, which often bear high transverse crests; and this character is so deeply impressed upon all known members of both divisions of the family that it probably was acquired at a relatively early date. And, if the above-described genus, *Apidium*, really be a forerunner of the Cercopithecidæ, it will be seen that an earlier stage in the development of this condition had been attained as far back as the Lower Oligocene.

In the existing cercopithecoid genera the steps by which these "bilophodont" molars have been derived are wholly wanting, but we know many analogous cases of the development of bilophodont molars from more primitive quadritubercular stages among the perissodactyls (tapirs, etc.), Eocene artiodactyls (*Tapirulus*), kangaroos and other groups, so that merely by analogy with these other cases we may infer that the bilophodont pattern of the upper molars in the Cercopithecidæ has been attained as follows:

(1) After the development of the secondary trigon and the obliteration of the primary trigon, as described in Part II, and after

(2) the progressive widening of the talonids and the correlated expansion of the "protocones," we have

(3) a lowering of the trigonid to the level of the talonid, and

(4) a secondary transverse widening of the trigonid, so that the trigonid and talonid become subequal in width; there is also

(5) a loss of the paraconid and

(6) a correlated outgrowth of the hypocone which articulates with the basin of the trigonid; meanwhile we have

(7) a coupling of protoconid and metaconid, of hypo- and entoconid, the latter pair articulating in the middle of the upper molars, which have now become quadrate in form and more elongate anteroposteriorly. The palæontological record, although incomplete, supports this interpretation since it affords the following structural stages:

(1) Lower Jurassic Trituberculata (especially *Amphitherium*): Early stage in the evolution of the talonid, upper molars with primary trigon retained, secondary trigon in early stage (see Part II).

(2) Paleocene insectivores: Primary trigon modified, secondary trigon developing, upper molars tritubercular, lower molars tuberculosectorial.

(3) Lower Eocene tarsioids: Primary trigon obliterated by wide separation of para- and metacones and great expansion of "protocones;" lower molars with wide but low talonids and small high trigonids.

(4) Upper Eocene tarsioids (e.g., *Microchærus*): Upper molars more or less quadritubercular through upgrowth of hypocone, but tritubercular ground plan still evident; second lower molars with subequal trigonid and talonid; a hypoconulid.

(5) Lower Oligocene *Apidium*: Upper molars unknown, but (as shown by the structure of the lower molars) necessarily quadrate, elongate anteroposteriorly, and with incipient pairing of the four main cusps, dividing the crown into anterior and posterior moieties; second lower molars elongate, m_2 with trigonid and talonid subequal in width, four main cusps conical, paired but not joined by transverse crests; paraconids reduced, hypoconulids prominent, double on m_3, an accessory cusp at the anterior end of the crista obliqua on all three molars.

(6) Lower Miocene *Oreopithecus*: Upper molars anteroposteriorly elongate; four main cusps conic, paired but not connected by transverse crests; lower molars fundamentally as in (5) but opposite cusps more distinctly paired.

(7) Lower Pliocene *Dolichopithecus*: Fundamentally as in (6), but paired cusps in both upper and lower molars bearing high transverse crests; reduction of the hypoconulid, except on m_3.

The early pairing of the molar cusps in groups of two, together with the relative unimportance of the hypoconulid, are conspicuous characters which definitely rule all cercopithecoid monkeys out of the line of ascent leading to the anthropoid apes and man.

FIG. 232. *Erythrocebus albigenis.* × 4/5

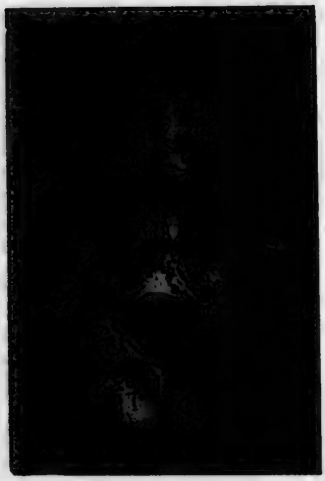


FIG. 231. *Miopithecus talapoin.* × 4/5

FIG. 233. *Pithecus brevicaudus.* × 4/5

FIG. 230. *Miopithecus talapoin.* × 4/5

FIGS. 230 TO 234, INCLUSIVE. COMPARATIVE SERIES: SKULLS OF SEMNOPITHECINÆ AND OF CERCOPITHECINÆ. SKULLS AFTER ELLIOT, REARRANGED

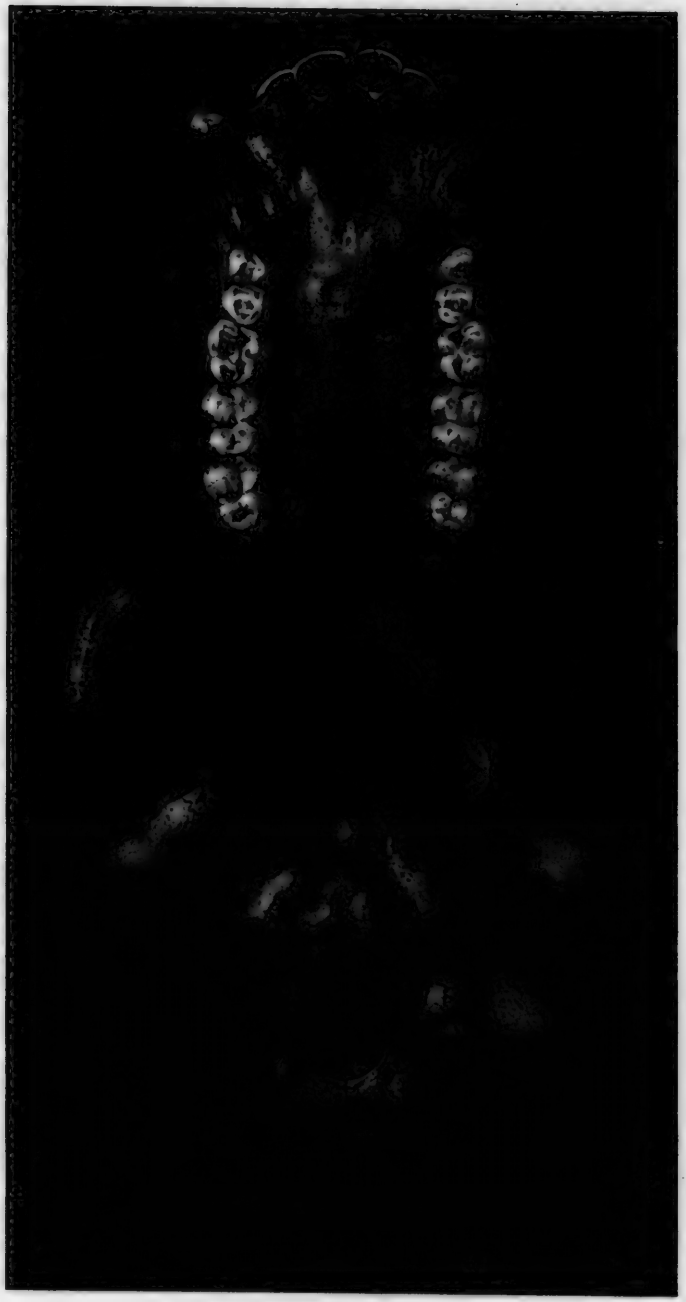


FIG. 234. *Papio cynocephalus.* × 3/4

II. ORIGIN AND RISE OF THE ANTHROPOID APES (SERIES CATARRHINÆ, FAMILY SIMIIDÆ)

PROPLIOPITHECUS, FROM THE LOWER OLIGOCENE OF EGYPT, AND THE ANCESTRY OF THE GIBBONS (SUBFAMILY HYLOBATINÆ)

Propliopithecus. This important stage of evolution is so far known only from an incomplete lower jaw from the Lower Oligocene of Egypt, which was appropriately named *Propliopithecus haeckeli* by Schlosser in 1911. Fortunately the teeth are so highly characteristic and so much like those of the later *Pliopithecus* in general plan that there can be no question that *Propliopithecus* is an early and relatively

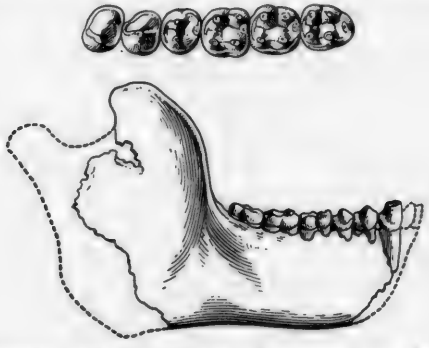


FIG. 235. *Propliopithecus haeckeli*. LOWER OLIGOCENE, FAYÛM, EGYPT. AFTER SCHLOSSER

Lower jaw. × 1. Left lower teeth (canine to m_3, inclusive). × 3/2

primitive representative of the anthropoid stock. As compared with the jaws of modern gibbons that of *Propliopithecus* is much more primitive in respect of the following characters:

(1) The lower canines were not much enlarged and the anterior lower premolars were not compressed, elongate or sectorial, but anteroposteriorly shorter, more like those of the contemporary *Parapithecus*. Hence (although such an inference may appear unscientific to skeptics who insist on waiting for "more fossils"), it is safe to infer that the upper canines were of relatively small size, not greatly enlarged and sabre-like as they are in the modern gibbons and siamangs.

(2) As the whole jaw is shorter and relatively deeper than those of gibbons and siamangs, and as the upper canines were evidently not tusk-like, it is extremely probable that the dental arches were shorter, and more convergent in front.

(3) The relatively small size and vertical position of the lower canine, and the shorter, more convergent dental arches, indicate a correspondingly shorter face and probably less pronounced progna-

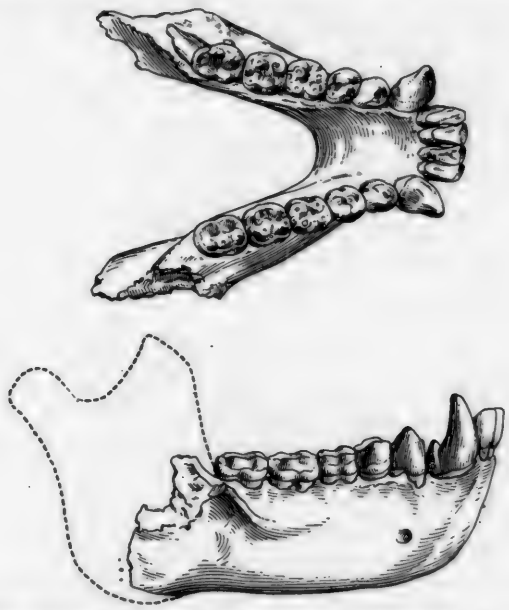


FIG. 236. *Pliopithecus antiquus*. LOWER PLIOCENE, GERMANY. LOWER JAW AND DENTITION. × 1. FROM A CAST

thism than is common among recent gibbons. From these and other considerations it seems highly probable that the primitive anthropoids were less prognathous than their modern descendants, and that prognathism has increased *pari passu* with the enlargement of the canines, and (except in the gibbons) with the widening of the central incisors.

As noted by Schlosser, *Propliopithecus* is structurally allied with and probably ancestral to *Pliopithecus* of the Upper Miocene and

Lower Pliocene of Europe, which in turn leads to the modern gibbons. The conclusion supported by the writer is that *Propliopithecus*, standing in or near the base of the gibbon line, also affords an early stage of the dentition that is structurally intermediate between the lower, more tarsioid *Parapithecus* and some primitive *Dryopithecus*-like

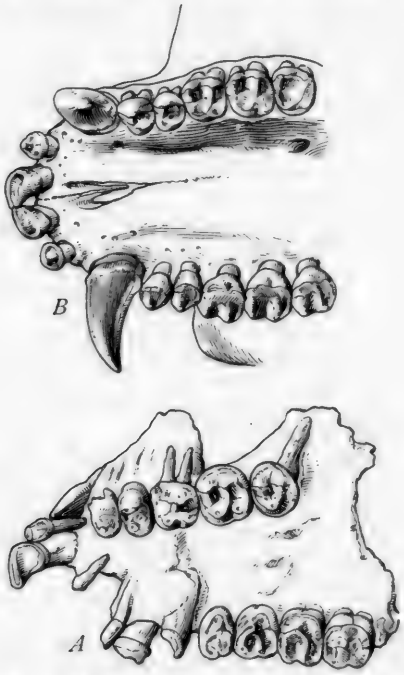


FIG. 237. COMPARISON OF (A) *Pliopithecus antiquus*, AFTER HOFFMANN, AND (B) *Hylobates lar*. × 1.

This figure well illustrates the relatively close structural and genetic relationships of these genera. The modern genus has become specialized in the widening of the median incisors, in the laniary form of the canines, in the anteroposterior elongation of the premolars and in the reduction of the cingulum of the molars.

stage, which would be the common starting-point for the main branch leading to the anthropoids and to man.

Pliopithecus. The dentition and relationships of this important form are discussed in the following passages quoted from my "Studies on the evolution of the primates" (1916, pp. 301–305):

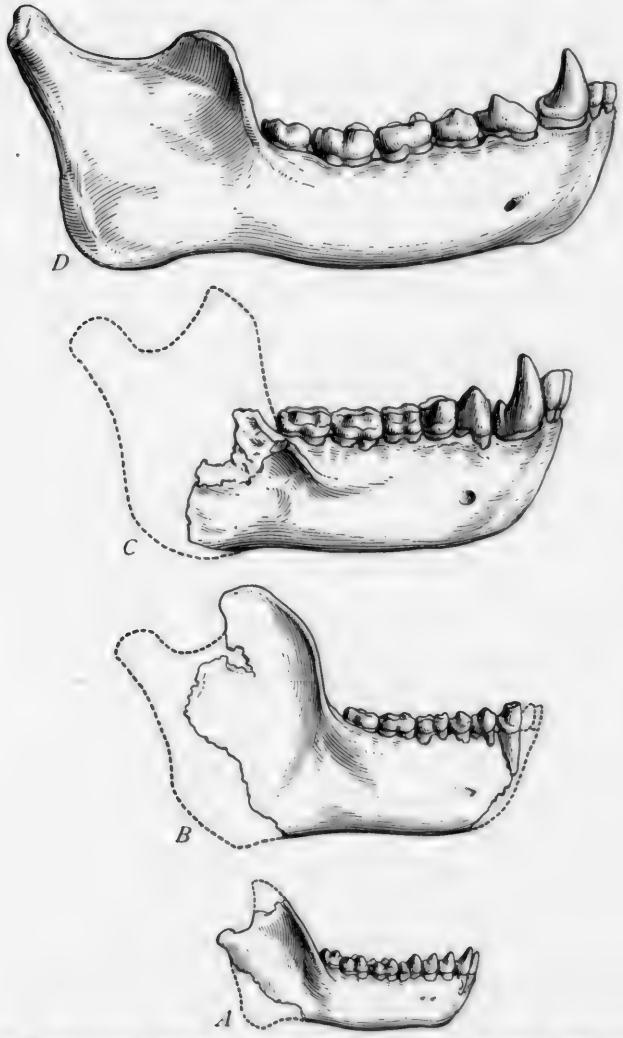


FIG. 238. COMPARATIVE SERIES: LOWER JAWS OF *Parapithecus* AND HYLOBATINÆ. × 1

A.—*Parapithecus fraasi*. Lower Oligocene, Fayûm, Egypt. After Schlosser.
B.—*Propliopithecus haeckli*. Lower Oligocene, Fayûm, Egypt. After Schlosser.
C.—*Pliopithecus antiquus*. Lower Pliocene, Germany. From a cast.
D.—*Symphalangus syndactylus*. Recent, Asia. After De Blainville, modified from specimens.
Missing parts restored hypothecially in broken lines.

"This Upper Miocene and Lower Plicocene genus has been regarded by nearly all authors except Dubois (1897) and Pilgrim (1915) as an ancestral gibbon, Hoffman (1893) after a very careful investigation even placing it in the genus *Hylobates*. Its resemblances to the gibbons are indeed so numerous and so fundamental that I do not doubt that it is at least structurally ancestral. Dr. Pilgrim (1915) on the contrary thinks it is excluded from the direct ancestry of the gibbons by at least the following characters:

(1) The greater proportionate breadth of the teeth in the front of the jaw in *Pliopithecus* particularly marked in the case of pm_3, but noticeable in the premolars, upper as well as lower, and in the first molar above and below.

(2) The much longer symphysis in *Pliopithecus*.

(3) The greater divergence of the mandibular rami.

"But, to deal with these in reverse order, why is the greater divergence of the mandibular rami regarded as a specialization in *Pliopithecus*, and why are the more parallel rami of the gibbons regarded as more primitive? From the reduction of the dental formula and crowding out of one pair of incisors and the two anterior pairs of premolars in all Old World Anthropoidea, and from the evidence that all this series eventually ran back into small insectivorous-frugivorous, short-faced lemuroids analogous to *Necrolemur* and the Anaptomorphidæ, it seems quite probable that in the remote ancestors of the series the front of the jaw was quite narrow, with small semi-procumbent canines and incisors, the mandibular rami divergent rather than parallel. Such a jaw, as shown above, is already known in the Lower Oligocene *Parapithecus*. On the other hand the parallel rami, wide muzzles and chins of the gorilla, chimpanzee and orang are obviously correlated with the widened incisors and tusk-like canines. The gibbon, too, has acquired almost sabre-like, wide-spread, although slender, upper canines, and somewhat wider incisors; in connection with these features its jaw has widened distally and its mandibular rami have become parallel rather than convergent. To the same sabre-like form of the canines as a primary adaptation may reasonably be credited the elongate compressed form of the front lower premolar, as well as the oblique downward prolongation of the front portion of its crown, features developed in far greater degree in the baboons, where their association with the tusk-like form of the upper canine is very obvious. *Pliopithecus*, on the other hand, in the divergent rami, in the smaller canines and in the wider premolars, has retained the characters seen in greater emphasis in the far older Oligocene genus *Parapithecus*.

"The greater width of the upper premolars in *Pliopithecus*, as compared with the gibbons, means only that in the gibbons the relative anteroposterior diameter of these teeth has increased, perhaps in correlation with a slight lengthening of the premolar region in the lower jaw, and the same is true of the greater relative width of the first upper and lower molars. As noted above, in many mammals there is often a tendency for molars to transform from a relatively wide and triangular crown to an anteroposteriorly elongated quadrangular crown. This tendency has affected the gibbon far less than the gorilla, but the gibbon has not escaped it entirely, as the foregoing comparison with *Pliopithecus* indicates. The greater breadth of the lower premolars in *Parapithecus* and *Propliopithecus* by no means excludes them from the ancestry of the gibbons. In the remote forerunners of the whole anthropoid series there was, as above noted, a marked fore-and-aft crowding of the front of the jaw, a process seen also in the Anaptomorphidæ, where it also results in a relative widening of the premolars.

"As for the much longer symphysis in *Pliopithecus*, that is associated perhaps with the far heavier mandibular rami, very wide ascending ramus and heavy jaw muscles. Such a type of jaw is clearly foreshadowed in *Propliopithecus* and is carried to an extreme in the male orang. While there is a truly amazing variation in the form of the jaw in the siamang, as shown by Bolk (1915), the very slender-jawed types with a weak symphysis have a degenerate look, which, as in the case of certain Cebidæ and Lemuridæ is, I believe, a late acquisition.

"Among the characters which in Dr. Pilgrim's view tend to exclude *Propliopithecus* and *Pliopithecus* from the ancestry of the gibbons is 'the fact that m_3 is shorter than m_2.' 'There can, however, be no doubt,' continues Pilgrim (p. 63), 'that the latter character is typical of an advanced stage of evolution.' But in the far older Anaptomorphidæ of the Lower and Middle Eocene, m_3 is usually a *smaller* tooth than m_2 and is sometimes even shorter. The further fact that it is shorter than m_2 in both the known Oligocene genera, *Propliopithecus* and *Parapithecus*, suggests that this is a primitive character rather than that these genera should be excluded from the ancestry of *Propliopithecus* and the gibbons.

" 'The question of the canines in this branch merits consideration,' says our author (*loc. cit.*). 'Are the small canines in *Propliopithecus* an instance of precocious reduction, similar to what has occurred at an extremely recent period in the case of the Hominidæ, or were the canines of the Anthropoidea primitively small? The answer to this can only be hazarded as a guess.' But to the present writer the evidence on this matter seems fairly decisive. The canines are quite small in most of the Lower Eocene

Anaptomorphidæ and in the oldest known anthropoid, *Parapithecus*. In *Propliopithecus*, *Pliopithecus* and *Dryopithecus* the progressive enlargement of the canines can be traced to its extreme development in the modern giant apes. Dr. Schlosser's view is that in the Primates generally the canine may have originated as a front premolar which gradually became caniniform, and that the original lower canine came to function as an incisor. This hypothesis, although favored by Dr. Pilgrim (p. 64), is, in my judgment, totally erroneous and based upon a false analogy supplied by the Lemuridæ. For the lower canine of all anthropoids and in the Adapidæ and Cebidæ fits in front of the first maxillary tooth, which is surely an upper canine. Hence the lower canine of anthropoids is homologous with the lower canine of lemuroids.

"In conclusion it may be remarked that the present writer during the past fifteen years has had perhaps unusual opportunities for studying the evolution of the teeth in many phyla of mammals. From this experience has grown the impression that *mere quantitative differences in degree, or in proportion, should not in themselves and without further evidence be deemed sufficient to exclude an earlier form from the ancestral line of a later form*. In many cases I believe that there are marked changes and even reversals in the trend of evolution as we follow the lines onward—of which many fairly well attested instances might be cited.

"Such a reversal of trend may well be illustrated in the history of the dentition in the line leading to the gibbons. At a very remote period, perhaps in the Lower Eocene, there was probably a marked anteroposterior crowding of the front part of the lower jaw, with a consequent elimination of one incisor and two premolars on each side, and a widening of the lower premolars, this stage being represented by *Parapithecus* and *Propliopithecus*. Subsequently there was a secondary increase of length in the front part of the rami, associated with an increase of length in anteroposterior diameter and a decrease in width in the lower premolars, a rapid enlargement of the canines, a widening of the distal end of the jaw and a parallel realignment of the lower tooth rows.

"In brief it appears to the present writer that the genera *Parapithecus*, *Propliopithecus*, *Pliopithecus*, *Hylobates* (in the broad sense) offer a fairly good series characterized by the following changes: (a) increasing verticality of the incisors, (b) sabre-like elongation of the upper canines, (c) shortening and widening of the symphysis, (d) anteroposterior lengthening of the premolars, (e) weakening of the body of the mandible, (f) rounding of the molar crowns and of all the molar cusps."

The modern gibbons. The following discussion of the cranial and dental characters of the modern gibbons (*Hylobates*, *Symphalangus*) is quoted from "Studies on the evolution of the primates" (1916, pp. 272–273):

"Of the existing anthropoids the gibbons are on the whole the most primitive in skull and dentition. On the other hand, as compared with primitive Eocene lemurs (*Notharctus*, etc.), they share with other anthropoids and Old World monkeys the following characters:

the shortening of the face,
the narrowing of the olfactory region,
the forward growth of the orbits and frontals,
the progressive separation of the orbital and temporal fossæ,
the great widening of the braincase,
the backward growth of the occipital portion of the braincase,
the beginning of the downward deflection of the facial part of the skull.

"In their incipient stages all these characters were doubtless characteristic of the ancestral catarrhine primates as a whole and are to be regarded as primarily specializations for arboreal existence; they are correlated in part with a progressive enlargement of the cerebrum and a reduction of the olfactory portions of the brain. At the same time they foreshadow the end specializations of higher types.

"The bony posterior walls of the orbits separate the eye and its muscles from the powerful temporal muscles, which are inserted on the posterior rim of the protruding orbits as well as on the sides of the braincase. This voluminous anterior extension of the temporal insertion-area, together with the forward pushing of the braincase, has no doubt conditioned in part the forward growth of the orbits, the shutting off of the orbits from the temporal fossæ, and the retraction of the face.[2] There is no sagittal crest, the opposite insertion-areas of the temporal muscles being widely separated by the flattened parietal vertex.

"The jaws and dentition of the gibbons, as in all other anthropoids, are adapted chiefly for a frugivorous diet. The gibbons are more primitive than the other anthropoids in retaining the sub-tritubercular upper molars, in which the primitive trigonal pattern of the crown is only a little modified by the upgrowth of the postero-internal cusp, or hypocone, the inner side

[2] No doubt the forward shifting of the orbits has also been in correlation with the approach toward, and final attainment of, the ability to focus both eyes on a nearby object.

FIG. 239A. SKULL OF *Hylobates lar*. × 4/5. AFTER ELLIOT

FIG. 239B. SKULL OF *Symphalangus syndactylus*. × 4/5. AFTER ELLIOT

FIG. 240A. SKULL OF *Hylobates lar*. × 4/5. AFTER ELLIOT

FIG. 240B. SKULL OF *Symphalangus syndactylus*. × 4/5. AFTER ELLIOT

of the crown still being narrow and supported by an undivided root. All the molars lack the folds and wrinklings that are seen in the higher anthropoids. The lower molars have the four main cusps and the postero-median cusp, or hypoconulid, which are characteristic of the anthropoids and man. The middle part of the crown as in all primates forms a broad basin

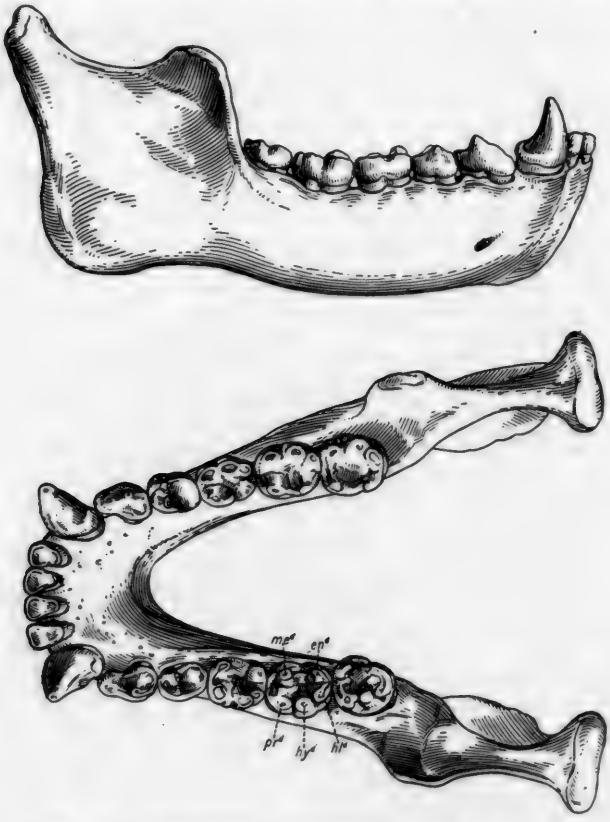


FIG. 241. *Symphalangus syndactylus.* LOWER JAW. × 1

for the reception of the main internal cusps (protocone) of the upper molars. The small premolars, or bicuspids, which, as in other catarrhines, are reduced to two above and below on each side, testify to the former loss of the two anterior premolars of the primitive placental dentition and to the marked shortening of the face in the remote ancestors of the gibbons.

The very large sabre-like canines may be either a defensive specialization or, more probably, a frugivorous one. The assumption of the tusk-like form has evidently conditioned the deepening of the anterior part of the lower jaw, the firm union of its opposite halves, and the rapid upward slope of its posterior border. The slenderness of the horizontal ramus is in all probability a retrogressive character: first, because in all other anthropoids the ramus is deep; secondly, because there is wide variation in this character in the genus *Siamanga* (see Bolk, 1915); and thirdly, because an analogous reduction of the ramus is seen in the Cebidæ in several genera.

"The incisors of the gibbons have remained rather primitive in form and consist of small procumbent, chisel-like teeth, well adapted for holding and cutting fruits, the inner pair being only slightly enlarged and not excessively wide as in higher anthropoids.

"Certain skull characters are undoubtedly connected with the upright pose of the gibbons, both in sitting and progressing, especially the downward facing of the foramen magnum, which brings the head at a sharp angle to the vertebral column."

An important conclusion of the foregoing discussion is that the sabre-like form of the upper canines and the sectorial form of the anterior lower premolars of the gibbons are relatively late specializations.

The gibbons are intermediate between the cercopithecoid monkeys on the one hand and the true Simiidæ or anthropoids on the other, so that they are often set apart as a distinct family, Hylobatidæ. Thus they agree with the Cercopithecidæ in many significant characters of the brain (Keith), in the lack of a frontal sinus, in the possession of large ischial tuberosities, in the persistence of the fossa subarcuata in the periotic bone of the adult, and in many other features of the anatomy, so that Keith (1896, p. 396) regards them as essentially cynomorph monkeys. But these are all primitive characters; and in the other direction the gibbons are widely removed from the cynomorphs and definitely allied with the anthropoids by the characters of the dentition, by the brachiating adaptations of the skeleton, and by the erect mode of progression on the ground. Also the palæontological evidence reinforces the conclusion that the gibbons, by derivation from *Propliopithecus* or some closely allied genus, are also related with *Dryopithecus chinjiensis*, and the other anthropoids and widely removed from the cynomorphs. The suggestion of

various authors, especially Pilgrim (1915), that the gibbons and their predecessors stand relatively near the line of human ascent is discussed below (p. 693).

ZOÖGEOGRAPHIC RELATIONS OF EUROPE, ASIA, AND AFRICA, DURING THE EOCENE AND MIDDLE TERTIARY EPOCHS

Before taking up the dentition of the Miocene and Pliocene anthropoids it may be well to consider briefly some of the probable zoögeographic relations of Europe, North Africa, Western Asia, and India, during middle and later Tertiary ages, as described especially by Osborn (1910), Matthew (1912), and Andrews (1906).

During the long Eocene epoch numerous genera and species of primates flourished in central Europe, including various lemuroids and tarsioids, but the whole catarrhine division of the primates is conspicuous by its absence. North Africa at some very early time must have been connected by land either with Europe or western Asia, for in the Lower Oligocene of Egypt we find various mammals that are rather closely related to their European contemporaries (e.g., primitive artiodactyls, hyænodont carnivores, etc.) along with other groups that had apparently been evolving in Africa for many ages (arsinoitheres, hyracoids, etc.). Among these are the catarrhine primates, including *Parapithecus*, *Propliopithecus*, *Mæripithecus* and probably *Apidium*. Although perhaps remotely related to the *Necrolemur*-like tarsioids of the Upper Eocene of Europe, these Egyptian primates represent a very distinct family, not known from any other region, and probably derived from some early Eocene immigrants from Europe or possibly from southern Asia. Fortunately the genera named above afford clues, first as to the origin of the whole series from some unknown genera of tarsioids, and secondly as to the divergence of the cercopithecoid and anthropoid-man stocks; although it may well be that there were other genera in existence at that time which would supplement our knowledge of the more precise interrelationships and detailed stages in the evolution of the dentition.

Europe, North Africa and Eastern Asia were more than once in contact during the long mid-Tertiary ages; for we find such faunas as the *Hipparion* fauna of the Miocene spreading over this immense

region so widely that it is often impossible to be sure in what part of the range a particular group originated. Hence there has been some doubt whether the primitive proboscideans, for example, which are found along with the above-named primates in the Lower Oligocene of Egypt, originated in North Africa or in western Asia, where somewhat more advanced forms are found in the succeeding ages. The proboscideans may have reached India from North Africa by way of Baluchistan, where successors of the Egyptian *Palæomastodon* have been reported by Pilgrim and by Forster-Cooper (1915, pp. 409, 410), and the primitive anthropoids may have followed the same path. On the other hand the Indian primates about to be described may have been derived from some Upper Eocene distribution center other than North Africa, such as Burma, where a characteristic Upper Eocene fauna of hoofed mammals has lately been discovered (Pilgrim and Cotter, 1916). At any rate the Middle Miocene beds of the Siwalik Hills in northern India contain teeth and fragments of jaws of three genera and four species of anthropoid apes, described originally by Pilgrim (1915), which are of the greatest importance in the problem of the origin of the modern anthropoids and even of man himself.

THE MIOCENE AND PLIOCENE ANTHROPOIDS AND THEIR MODERN DESCENDANTS

The following general remarks on the fossil primates of India are quoted from "Studies on the evolution of the primates" (1916, pp. 285–286):

"As described by Lydekker in 1886, the fossil primates of India included extinct species of macaques, baboons and semnopitheques, and two anthropoid apes apparently related respectively to the orang and the chimpanzee. This composite assemblage of genera now widely separated in Africa and Asia tended to confirm the faunal kinship of these continents with each other and with Europe during the later Tertiary and inspired the hope that eventually the Siwaliks series would yield important evidence on the origin and interrelationships of the great apes and man.

"In recent years the Geological Survey of India has secured more of these fragmentary but very important fossils, which have lately been

accurately described and figured by Dr. Guy E. Pilgrim in a memoir entitled 'New Siwaliks Primates and their bearing on the question of the evolution of man and the anthropoidea.'

"According to Pilgrim the Primates of India appear first in the Chinji zone (Lower Siwaliks) which is regarded as of Lower Sarmatian (Upper Miocene) age; they extend through the Nagri and Dhok Pathan zones (Middle Siwaliks) of Pontian or Lower Pliocene age, and culminate in the upper zones of the Upper Siwaliks of Upper Pliocene age.

"All belong exclusively to the catarrhine or Old World division of the suborder Anthropoidea. More in detail the Lower Siwalik series (Chinji zone, Upper Miocene) includes: (a) two species of *Dryopithecus*, a primitive genus of the great apes, hitherto known only in the Upper Miocene and Lower Pliocene of Europe; (b) *Palæosimia*, a supposed ancestor of the orang, and (c) *Sivapithecus*, a genus regarded by Pilgrim as related to the ancestors of the Hominidæ.

"The Lower Middle Siwalik series (Nagri zone, ?Upper Miocene) includes a gigantic species of *Dryopithecus* (*D. giganteus*). The Upper Middle Siwalik series (Dhok Pathan zone, Lower Pliocene) includes *Palæopithecus*, an anthropoid which was regarded by Lydekker as closely related to the gorilla and chimpanzee.

"The Upper Siwaliks (Upper Pliocene) include an orang and several species of macaques, baboons, and semnopitheques.

"Through the kindness of Dr. Pilgrim the American Museum of Natural History has secured casts of the principal types of Siwalik anthropoids and these, together with the extremely accurate figures given in Dr. Pilgrim's memoir, have enabled the reviewer to make careful comparisons with other recent and fossil anthropoids."

As the Middle Miocene anthropoids are more than a whole geological epoch later than the Lower Oligocene apes of Egypt, they are naturally far advanced in structure towards their modern relatives and descendants, the orangs, chimpanzees, gorillas and possibly man. As compared with *Propliopithecus* they are already "giant apes," and unlike that genus none of them seems to be closely related either to *Pliopithecus* or to the modern gibbons. In the Upper Miocene and Pliocene of Europe we find fragmentary specimens of anthropoids, some of which (*Pliopithecus*) may be descended from the Lower Oligocene genus *Propliopithecus* of North Africa, while others (*Dryopithecus*) are more closely related to the anthropoids of India.

Palæosimia. Of the Middle Miocene Indian anthropoids, *Palæosimia* is known only from a third upper molar (*fig. 242*) which, as noted by Pilgrim, shows significant agreement with that of the orang, but is much more primitive and is related also to the contemporary genus *Dryopithecus.* The following is quoted from "Studies on the evolution of the primates" (p. 287):

"This anthropoid is represented only by the third upper molar of the right side. As observed by Pilgrim, this tooth distinctly foreshadows that of the orang in its general pattern and in the characters of the enamel folds and wrinkles, the differences all being obviously primitive characters.

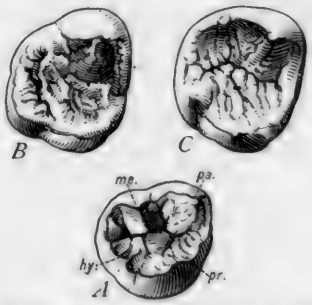


FIG. 242. COMPARISON OF RIGHT UPPER THIRD MOLAR OF (A) *Palæosimia*, WITH (B, C) MODERN ORANGS

A.—*Palæosimia rugosidens.* Upper Miocene, Lower Siwaliks, India. After Pilgrim. B, C.—*Simia satyrus.* After Selenka.

In *Palæosimia* the third upper molar is of relatively primitive form, showing affinities with *Dryopithecus.* In the modern orangs, m^3 is variable in form and the surface is much wrinkled.

This specimen comes from a low horizon (Chinji zone) and its characters suggest that the orang line had even at that time become rather widely separated from the forerunners of the chimpanzee and gorilla. Accordingly Dr. Pilgrim considers *Palæosimia* 'as branching off from the *Dryopithecus* line previous to the chimpanzee and gorilla and passing through a marginal hypothetical species of Dryopithecus'."

The orang-utan. The orang line is represented in the Upper Pliocene Siwalik series of India by a lower jaw. Thus the orangs probably became differentiated in the lower Miocene from the primitive giant ape stock in the region of northern India, but during later times were

pressed southward to their present habitat in Borneo and Sumatra. During the vast time since the Miocene, the orangs have become highly specialized for arboreal life and for feeding upon fruits with heavy rinds, which they are able to pierce with their heavy jaws and large front teeth. No doubt the brain and braincase have also increased in size during the same period. In many respects they have become

FIG. 243. HEAD OF BORNEAN ORANG, *Pongo* (*Simia*) *pygmæus*. AFTER ELLIOT

remarkably specialized and highly variable in structure. They are specialized in the deepening and rounding of the head and flattening of the face, close approximation of the orbits, extreme concavity of the facial profile, excessive wrinkling of the enamel on the molars, etc. They are extremely variable in the contour of the face, degree of prognathism, form of dental arches, overbite, and other characters noted by Selenka (1898–1903), Elliot (1912), and Hellman (1918).

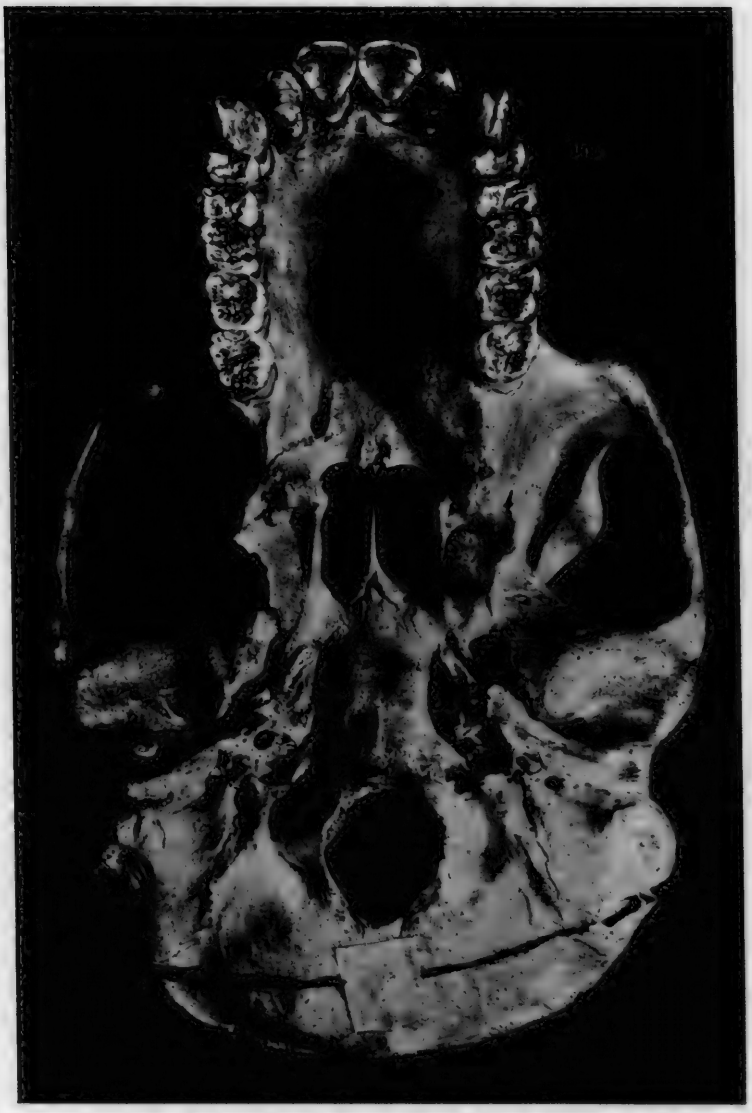


FIG. 244. SKULL OF BORNEAN ORANG, *Pongo* SP. × 2/3

In this specimen the upper dental arch somewhat resembles the supposed prehuman type. The excessive wrinkling of the enamel on the molars is well shown.

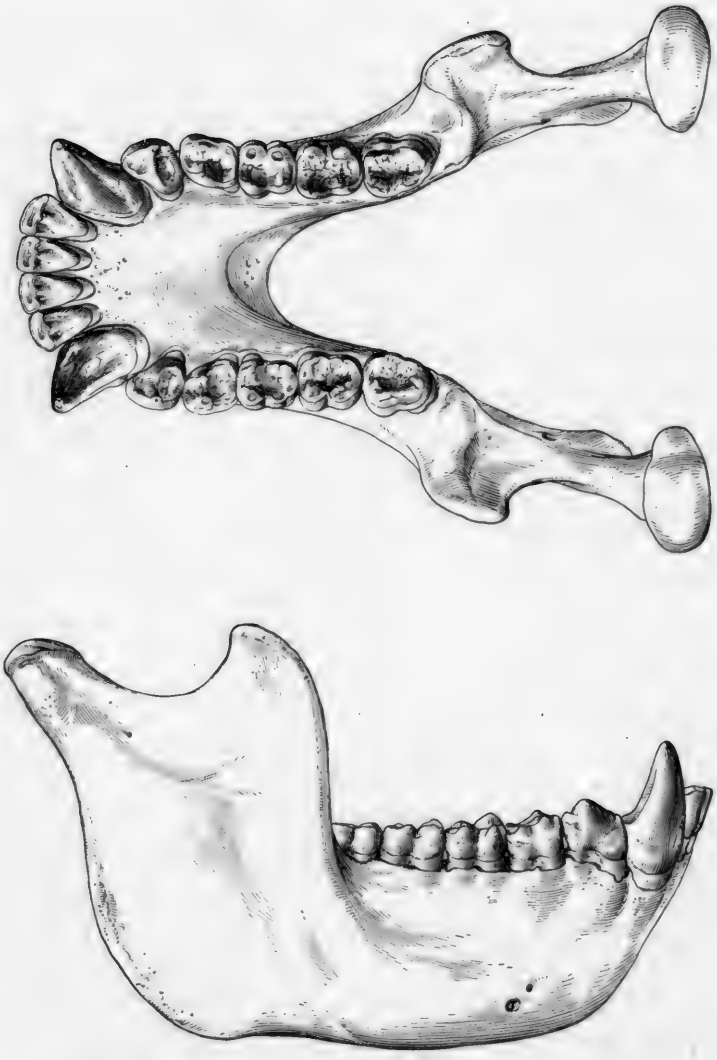


FIG. 245. LOWER JAW OF ORANG. *Pongo* (*Simia*) SP. × 2/3

The following description of the jaws and dentition of the orang is quoted from "Studies on the evolution of the primates" (p. 274):

"As in all other anthropoids the massive teeth, jaws, and jaw-muscles are specialized for a frugivorous diet, the orang being able to tear open the tough rind of the fruit of the durian. The upper molar teeth are fully quadritubercular with four-sided rather than triangular crowns. The surface of the crowns is low and flat with very numerous fine wrinklings on the enamel—an advanced specialization. The protocones or anterior internal cusps are only faintly connected with the external cusps, the para- and metacones. The premolars are relatively stouter than in the gibbon. The stout canines are highly effective in opening fruit and in fighting. The central upper incisors are very broad with flattened posterior faces. The long-crowned incisors and canines, as seen from below, form an evenly rounded or arched series.

"The massive deep lower jaw has a wide distal end and a broad, high ascending ramus; the condyle is raised above the level of the coronoid, in correlation with the forward displacement of the braincase and the downward and backward displacement of the muzzle. The lower anterior premolar is stout and less elongate than in the gibbon, but more elongate than in the chimpanzee. Its oblique antero-external slope is worn, as in other anthropoids, by the postero-internal face of the upper canine. The posterior lower premolar is approaching the molar pattern, especially in its posterior moiety. The lower molars have five cusps, as in other anthropoids, but the crowns are flatter and much wrinkled. The opposite premolar-molar series diverge slightly in front, in correlation with the widening of the muzzle and wide separation of the opposite canines at this point."

Although the orang skull may be described as a sort of caricature of an excessively brachycephalic, wide-faced human skull, these very superficial resemblances, mingled with many primitive characters common to the anthropoids-man stock, have never deceived competent students of the subject, who have always recognized that of the three modern giant apes the orang is in many respects the furthest removed from man. For reasons which will be developed later it seems highly probable that the orang line separated from the giant ape-man stock *before* its subdivision into chimpanzee, gorilla and human lines. Nevertheless the orang affords some interesting par-

FIG. 246. SKULL OF ORANG, *Pongo (Simia) pygmæus*. × 1/2. AFTER ELLIOT

allels to human conditions in the variable occlusal relations of the upper and lower incisors (edge-to-edge or extreme overbite) and in the wide variability in the upper and lower dental arches (Hellman, 1918).

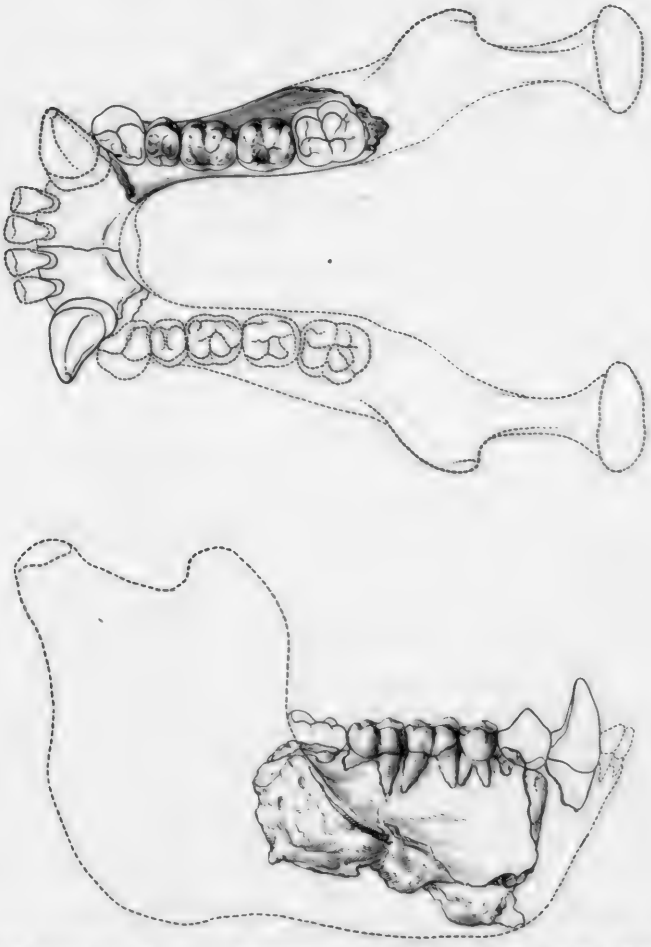


FIG. 247. *Sivapithecus indicus*. RECONSTRUCTION OF LOWER JAW, BASED ON CASTS OF TYPE AND REFERRED SPECIMENS. × 2/3

Hypothetical parts in broken line

Sivapithecus indicus. In my "Studies on the evolution of the primates" (1916, pp. 287–292) this interesting form was discussed as follows:

"This highly important genus and species were originally established on a third right lower molar (Pilgrim 1915, pl. 1, fig. 7) from the Chinji zone of the Lower Siwaliks, but the author employs as a neotype or topotype (wrongly called "type") a specimen from the same locality and level consisting of a right mandibular ramus (pl. 1, fig. 7), containing in excellent preservation the second and first molars, the posterior premolar and portions of the roots or alveoli of the anterior premolar and canine. A supplementary series from a later horizon (the Nagri horizon of the Middle Siwaliks) is referred by the author to the same species and consists of: (a) a fragment of the mandibular symphysis containing the left canine and parts of the roots and alveoli of the incisors and front premolar; (b) a front lower premolar; (c) a lower third molar. An upper canine from the Lower Siwaliks of Chinji is provisionally referred to the same genus, while a fragment of the right maxilla containing the much worn first and second molars are doubtfully referred to this genus.

"After an exceedingly detailed study of these precious fragments Dr. Pilgrim has attempted a preliminary and partly hypothetical restoration of the mandible of *Sivapithecus* in left side view and as seen from above. The reviewer has given prolonged consideration to this restoration, first with reference to the propriety of associating the scattered fragments in a single generic concept and secondly with reference to the placing and orientation of the various parts. While the generic association of the fragments seems probable the reviewer has been led to a different conception of the jaw as a whole. . . . .

"This anthropoid shows a rounding and broadening of the molar crowns, which in these particulars foreshadow the human type, although the first and second molars are more primitive and less widened than in man. The molar crowns present a widened modification of the '*Dryopithecus* pattern', described below, a pattern which is further obscured in man; the posterior premolar is bicuspid, and foreshadows the human type. Although the lower border of the mandible is not preserved, enough remains to show that the mandible was deep and massive, as it was in all early anthropoids and man. The ascending ramus was undoubtedly wide, as indicated by the forward extension of its lower outer ridge and by the massive character of the mandible.

"One of the most noteworthy human characteristics of *Sivapithecus* is the remarkable agreement in the breadth indices of all the lower cheek teeth as given by Dr. Pilgrim as follows:

	SIVAPITHECUS	MAN
m_3	93.7	91.6
m_2	94.6	94.4
m_1	92.1	92.0
pm_4	116.5	112.7
pm_3	110.1	111.6

"The premolars also approach the human type in fundamental pattern. . . . .

"By far the most unhuman features of the *Sivapithecus* jaw are the ape-like canine and front premolar. Those investigators who do not accept as a fact the frequent reversal of evolutionary tendencies, who expect very remote ancestors to foreshadow all the characters of their specialized descendants, and who, not finding such ancestors, make every group indefinitely polyphyletic and push all phyletic lines backward as nearly parallel lines meeting only at excessively remote periods, will undoubtedly see in the ape-like canines and front premolars of *Sivapithecus* an almost insuperable objection to close kinship with man. They will regard this genus as merely an extremely brachycephalic offshoot of the *Propliopithecus-Dryopithecus* group with no special affinity to the Hominidæ. At the other extreme, Pilgrim would remove it very far from all the Simiidæ and place it in or near the ancestral line of the Hominidæ, finding the common stem of Simiidæ and Hominidæ only in a remote and unknown Eocene common stock.

"The presence of ape-like canines and front lower premolars does not in itself necessarily exclude *Sivapithecus* from kinship with man, but rather, as Dr. Pilgrim thinks, it may well be a character which should perhaps be expected in a mid-Tertiary human precursor. However, even if it should be thoroughly established that *Sivapithecus* is directly ancestral to the Hominidæ, this would not, in the reviewer's opinion, warrant its removal from the Simiidæ to the Hominidæ, unless it could be shown that in the totality of its skeletal characters the genus was more manlike than ape-like."

Dryopithecus. This genus, including three species from the Miocene of India and three from the Upper Miocene and Pliocene of Europe, was discussed as follows in "Studies on the evolution of the primates" (1916, pp. 293–298):

"The genus *Dryopithecus* was formerly known only in the Upper Miocene and Pliocene of Europe. Several lower jaws with teeth have been described by Lartet, Gaudry, Branco, Harlé, A. S. Woodward. Isolated lower molars have been described by Branco, Abel, Schlosser and others. A couple of upper molars have been figured by Branco. The Indian material referred to this genus by Pilgrim is of similar fragmentary character, but is of great importance not only in further emphasizing the faunal affinities of the Siwalik series with the Upper Tertiary of Europe, but also in its bearing on the phylogeny of the anthropoids.

"The pattern of the lower molars of *Dryopithecus* may be broadly described as follows: There are five main cusps, three of which (protoconid, hypoconid, mesoconid) are on the external side of the crown and two (metaconid, entoconid) on the internal side. The metaconid, which is the highest cusp, is directly internal to the protoconid; the hypoconid is opposite the valley between the metaconid and the entoconid; the mesoconid (or hypoconulid) is on or near the postero-median border of the tooth, behind the hypoconid and entoconid. The external basal cingulum is more or less reduced but sometimes persists opposite the posterior part of the protoconid. In front of the protoconid and metaconid is a remnant of an earlier trigonid basin in the form of a transverse valley; into this depression fitted the hypocone of an upper molar. At the back of the tooth there is a very thick cingulum which sometimes is confluent with the mesoconid (hypoconulid). The surface of the lower molar crown is likewise characterized by the arrangement of certain furrows; the hypoconid is limited anteriorly and posteriorly by two deep transverse furrows which converge into a prominent inverted V (Λ), the narrow end of which is at the center of the crown. From the narrow end and sides of this truncated V, other furrows radiate as follows: (a) an anterior central furrow between the protoconid and metaconid, (b) a posterior central furrow between the mesoconid and entoconid, and (c) one or two internal furrows between the metaconid and entoconid.

"This general pattern is not only characteristic of all species of *Dryopithecus* both European and Indian, but also of the new genus *Sivapithecus*, which Dr. Pilgrim regards as ancestral to *Homo sapiens*. The *Dryopithecus* lower molar without doubt also reveals the fundamental ancestral pattern in the orang, gorilla, chimpanzee and even man, but it is more or less masked in each of these genera by secondary modifications. Judging from many analogies in other mammalian groups the *Dryopithecus*-pattern was ultimately derived, I believe, from the very primitive pattern exhibited in the genus *Parapithecus* Schlosser from the Lower Oligocene of Egypt; which is also structurally ancestral to the *Propliopithecus*-gibbon series.

"Although this conception of the morphology and relationships of the *Dryopithecus* molar is based upon the specimens figured by Gaudry, Schlosser, Abel, Branco, Harlé, Pilgrim and others, none of these authors should be considered as responsible for the present interpretation and formulation of the facts.

"Difficulty has been caused by the shifting relations of the hypoconulid ("mesoconid") to the mid-line in *Dryopithecus* and other primates. Branco

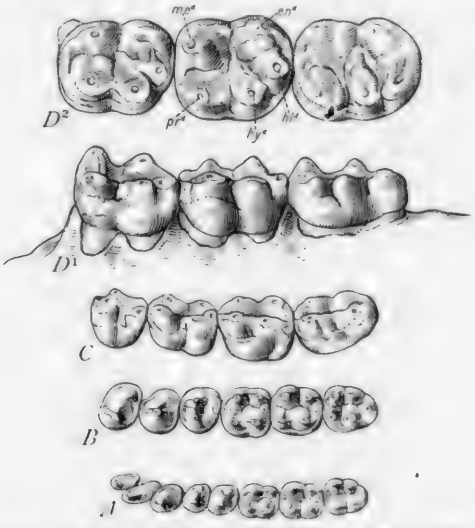


FIG. 248. COMPARISON OF LOWER TEETH OF *Parapithecus*, *Propliopithecus*, *Pliopithecus*, *Dryopithecus*. × 3/2

A.—*Parapithecus fraasi*. Lower Oligocene, Fayûm, Egypt.
B.—*Propliopithecus haeckli*. Lower Oligocene, Fayûm, Egypt.
C.—*Pliopithecus antiquus*. Lower Pliocene, Europe. Oblique view. After Abel.
D^1, D^2.—*Dryopithecus fontani*. Upper Miocene, Spain. After Smith Woodward. D^1, outer side; D^2, crown view.

Schlosser, Abel, and Pilgrim seem to have assumed that the primitive position of the hypoconulid is on the outer side of the crown in line with the protoconid and hypoconid and they speak frequently of an 'inward displacement of the mesoconid.' But a central position of this cusp is the primitive condition in many mammalian groups. It is seen in the Lower Eocene Anaptomorphidæ, it persists in the oldest known anthropoids, *Propliopithecus* and *Parapithecus* from the Lower Oligocene of Egypt, and continues into the *Pliopithecus*-gibbon line. Its position is variable in

Dryopithecus, where it is occasionally more or less displaced toward the outer side as it is more or less in the orang, chimpanzee, gorilla, and *Eoanthropus*. In all genera it is more central in the conservative first lower molar than in the more progressive second and third. It strikes behind the inner part of the metacone and externally to the hypocone of the upper molars. In the milk teeth it is often more or less central in position. In *Sivapithecus* it is intermediate in position, somewhat further inward than in Abel's 'second type' of *Dryopithecus fontani*. In man it is usually more median in position, especially in m_1, but is occasionally somewhat displaced to the outer side. The median position of the hypoconulid in man may be either a primitive or a secondary character. The frequent disappearance of the hypoconulid on the second and third molar in man is

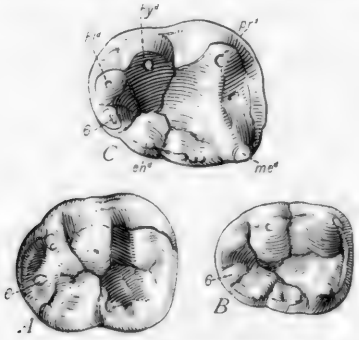


FIG. 249. COMPARISON OF THE LEFT LOWER THIRD MOLAR OF (A) *Dryopithecus chinjiensis*, (B) *D. punjabicus*, AND (C) *Gorilla* SP. × 3/2

A and B after Pilgrim

correlated with the rounding of the whole molar crown and with the rotary action of the lower jaw.

"*Dryopithecus chinjiensis* Pilgrim. The type consists of an isolated third lower molar from the Chinji horizon of the Lower Siwaliks. The author assigns this tooth to the genus *Dryopithecus* with some doubt; but that is evidently only because nowadays 'genera' are about equivalent to the old-fashioned 'good species.' The author's excellent figure of the type clearly reveals the generic pattern as described above and the differences between this tooth and those referred to *D. fontani* of Europe are no greater than the differences between the latter and the type of *D. darwini*. The author suggests that '*D. chinjiensis* . . . . might indeed even be the direct ancestor of the gorilla,' and a careful comparison of the figures

of the first and third lower molars (the only ones known) reveals striking fundamental resemblances to the corresponding teeth of the gorilla, the differences being all apparently primitive characters.

"*Dryopithecus punjabicus* Pilgrim. The specimens referred to this species are believed to have come from the summit of the Chinji zone (Lower Siwaliks) and from the lower part of the Nagri zone (Middle Siwaliks). The type consists of parts of the mandible containing the third right lower molar and the second left lower molar. The third lower molar shows all the generic characters above noted; its specific characters need not be considered here, except to note that it is elongate, tapering posteriorly, with low cusps, and with the internal margin broken up into numerous small cusps by sharp transverse furrows. It is more primitive than the third lower molar of the chimpanzee and it also suggests the contour of the third lower molar of the gorilla. The second lower molar is elongate,

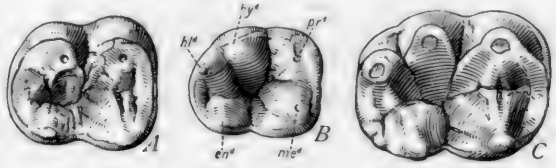


FIG. 250. COMPARISON OF THE LEFT LOWER SECOND MOLAR OF (B) *Dryopithecus punjabicus*, (A) ORANG, AND (C) GORILLA. × 3/2

B after Pilgrim

narrow posteriorly, and has an accessory cusp behind the metaconid. (Apparent vestiges of this cusp appear in certain chimpanzees.)

"The author refers to this species a specimen from the Nagri horizon of the Simla Hills, which is highly important, since it is a maxilla containing both premolars and the first and second molars in excellent preservation. The author observes that in comparison with the upper molars of the European species of *Dryopithecus* (as figured by Branco and by Schlosser) the Indian specimens agree so closely, apart from minute differences, as to make it fairly certain that they belong to the same genus. The author refers it to *D. punjabicus* on account of the 'remarkable analogy in structure and ornamentation of these molars and those of the Chinji mandible' (type), special points of resemblance being the serration of the outer edge of the tooth, the lowness of the cusps and the complex character of the enamel folding. To the reviewer these upper teeth, as well as the isolated ones figured in Pl. 2, figs. 4, 5, bear also a highly significant resemblance

to those of both the gorilla and the chimpanzee, not only in the general plan of each premolar and molar but also in a great many details.

"*Dryopithecus giganteus* Pilgrim. This species comes from a higher horizon, very near the boundary between the Lower and Middle Siwaliks, and is referred to the Nagri horizon of the Middle Siwaliks. The type and only known specimen is a third right lower molar, which is not only

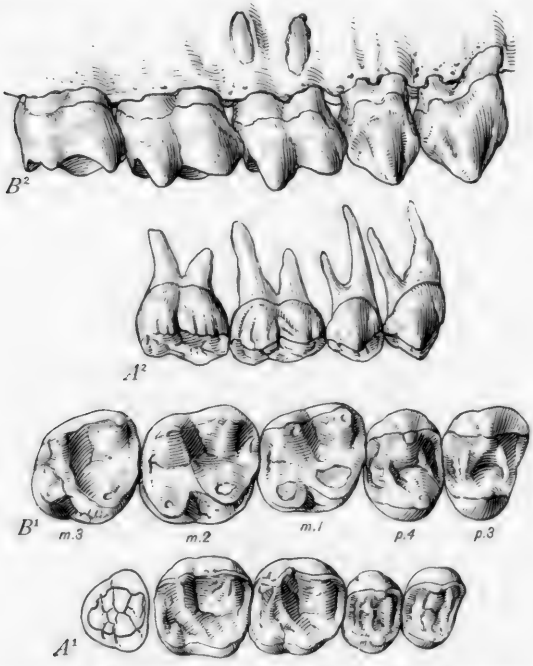


FIG. 251. COMPARISON OF UPPER CHEEK TEETH OF (A^1, A^2) *Dryopithecus punjabicus*, AND (B^1, B^2) GORILLA. × 1

A^1, A^2, after Pilgrim

much larger than that of any other species of the genus but also larger than that of the chimpanzee, in which this tooth is more or less retrogressive. To the reviewer this tooth is curiously suggestive of the corresponding tooth in certain chimpanzees, especially in the general pattern, course of all furrows, character and position of the wrinkles, the most important difference being the greater size and the fact that in the modern genus the posterior part of the tooth is usually narrower. *D.*

giganteus therefore appears to be rather closely allied to the ancestors of the chimpanzee. The wide range in size in the species of *Dryopithecus* is noteworthy.

"*Dryopithecus darwini* Abel. This species, from the Upper Miocene of the Vienna basin, is known only from the type, a third left lower molar.

"From the writings and illustrations of Professor Abel (1902, p. 34) and Dr. Pilgrim (1915, pp. 15, 70) we learn that the third lower molar of this species has the following characters: both in length (13.5) and breadth (11.8) it exceeds the other European species of the genus and also *D. punjabicus*, but is considerably smaller than *D. chinjiensis* and much smaller than *D. giganteus* (length 19.1, breadth 15.3). Its breadth-index exceeds that of allied species and equals that of the orang. The crown is low and

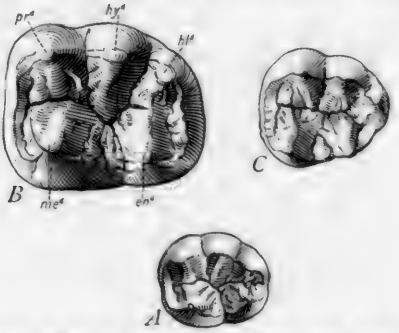


FIG. 252. COMPARISON OF RIGHT LOWER THIRD MOLAR OF (A) *Dryopithecus rhenanus*, (B) *D. giganteus*, AND (C) CHIMPANZEE. × 3/2

A, from a cast of a specimen figured by Branco; B, from a cast of the type

the anterior moiety is much wider than the posterior one. The protoconid is very large and the hypoconid narrow. There is a massive external cingulum which is arranged almost precisely as in *Pliopithecus antiquus*. The enamel folds and wrinkles are more numerous and stronger than in the other European species and the deep furrows that form the characteristic *Dryopithecus*-pattern fork at the ends. The inner side of the crown bears an accessory transverse furrow, as in *D. punjabicus*, *D. rhenanus*, and *Homo*. The hypoconulid ('mesoconid') is placed further in toward the center of the crown than in *D. fontani*.

"*D. Darwini* is undoubtedly widely different from Abel's 'second type' of *D. fontani*, in which m_3 is elongate with a weak cingulum and externally placed hypoconulid; but it approaches Abel's 'first type' of *D. fontani*, which is a wider tooth, with inwardly placed hypoconulid.

"From *D. rhenanus* the species under consideration is distinguished by its greater breadth, more wrinkled crown, more central hypoconulid. From two of the Indian species, *D. giganteus* and *D. chinjiensis*, it is readily distinguished, but it is less distinct from *D. punjabicus*, to which it may be allied. The strong basal cingulum, as noted by Abel, seems to be a primitive character derived from *Pliopithecus*-like ancestors.

"Professor Abel also notes that this tooth in its whole appearance and size, and in the arrangement and abundant branching of the furrows, approaches the men of Krapina; it differs, however, in the narrowness of the posterior moiety of the crown—a primitive character.

"*Dryopithecus fontani* Lartet. This species (*fig. 248*) is known chiefly from several lower jaws which have been figured by Lartet, Gaudry, Harlé,

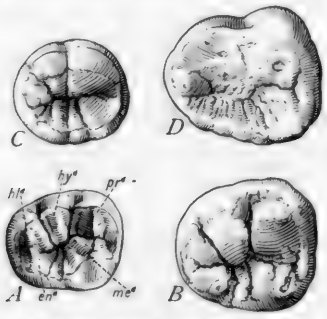


FIG 253. COMPARISON OF THE LEFT LOWER THIRD MOLAR OF (A) *Dryopithecus rhenanus*, (B) *D. darwini*, (C) STRANDLOOPER BUSHMAN, (D) ORANG. All × 3/2

A and B from photographs by Abel. Note the secondary furrows between the metaconid and the entoconid.

Smith Woodward, and others. Abel (1902, p. 33) has distinguished two types of this Upper Miocene age of France and Spain. In the first type the molars are a little wider than long, the hypoconulid is more central and posterior in position. In the second type the molars are considerably longer than broad and the hypoconulid is more external in position, almost as much as the hypoconid and protoconid. Both types have a weak basal cingulum on the front and outer sides.

"The third lower molar is a little smaller than in *D. punjabicus* which, according to Pilgrim (1915, pp. 14, 15), is distinguished further by minor details such as the absence of fine wrinkles and the absence of a serrated margin on the metaconid and entoconid. From *D. chinjiensis* and *D. giganteus* the species under consideration is distinguished by its smaller

size. The lower cheek teeth of *D. fontani* are of primitive anthropoid type of relatively small size, with few wrinkles, with considerable remnants of the external cingulum and a relatively short first molar.

"The jaw of *D. fontani* is of great interest on account of its relatively primitive character. The massive horizontal ramus is shorter than that of the gorilla, which is secondarily elongated. The region of the swollen symphysis is of generalized anthropoid type, as shown in Dr. Smith Woodward's comparative cross sections (1914, p. 317). *D. fontani* is, in one

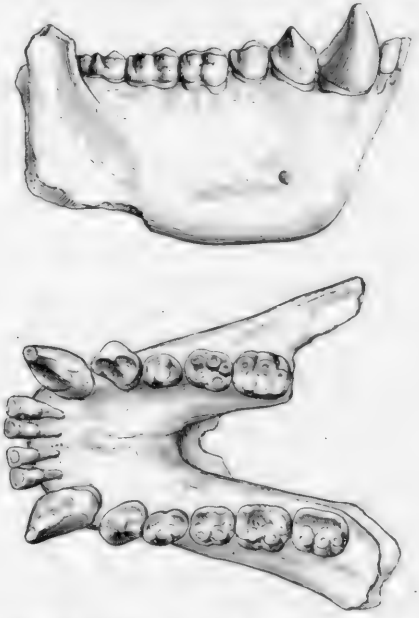


FIG. 254. *Dryopithecus fontani*. LOWER JAW. × 2/3. AFTER BRANCO

sense, a collateral ancestor of the gorilla, but perhaps not the direct ancestor, which may well be *D. chinjiensis* of India. In most characters it is intermediate between the far older *Propliopithecus* of the Fayûm and the modern gorilla.

"The varied relative lengths of the third lower molar in the anthropoids and man have led Dr. Pilgrim to exclude forms with a short m_3 from ancestral relations with those with a long m_3. The third lower molar in *Propliopithecus* is relatively and absolutely short. According to Pilgrim (1915, p. 72) the ratio of length of m_3 to that of m_2 in this genus is only 96.4 as

compared with 110.1 in *Pliopithecus*, in which the third molar is relatively very long. In the gibbons, m_3 is extremely short (80–88); in *Dryopithecus fontani* it is relatively much longer than in *Propliopithecus*, but only slightly longer than in the gorilla (101.2) and considerably longer than in the chimpanzee.

"Perhaps the majority of palæontologists of the present time, who believe in orthogenesis, the irreversibility of evolution and the polyphyletic origin of families, will assume that a short molar must keep on getting shorter, that it can never get longer and then again grow relatively shorter, and therefore that *Propliopithecus* with its extremely short third molar and *Dryopithecus* with its long m_3 are alike excluded from the ancestry of the gorilla, in which there is a slight retrogression in length of m_3. After many years of reflection and constant study of the evolution of the vertebrates, however, I conclude that 'orthogenesis' should mean solely that structures and races evolve in a certain direction, or toward a certain goal, only until the direction of evolution shifts toward some other goal. I believe that the 'irreversibility of evolution' means only that past changes irreversibly limit and condition future possibilities, and that, as a matter of experience, if an organ is once lost the same (homogenous) organ can never be regained, although nature is fertile in substituting imitations. But this does not mean, in my judgment, that if one tooth is smaller than its fellows it will in all cases continue to grow smaller. Frequently this is the case, but sometimes a relatively small member of a series will enjoy a secondary increase in size, or a relatively narrow structure will widen. Finally I believe that 'the polyphyletic origin of families' is to some extent a contradiction of terms; for if the families are of widely diverse or convergent origin then they are not natural. On the contrary natural families perhaps usually arise from a single genus or from closely allied genera.

"Hence I know no proved general principles which forbid us to believe that the last lower molar of anthropoids has always been rather variable in relative size; that it was at first small, but became larger and lengthened in *Pliopithecus* and *Dryopithecus*, becoming a little shorter in the gorilla, much shorter in the chimpanzee and excessively short in the gibbon.

"In the last named genus the sabre-like enlargement of the canines has thrown more work upon the masseter muscles and upon the malar bone and less upon the temporals. This may be associated with the retrogressive character of m_3. In the gorilla, on the contrary, although the masseters are large the temporals are of enormous size and hence the third lower molar is also large. In the chimpanzee the temporals are relatively smaller than in the gorilla and so also is the third molar. In man the temporals

are relatively small but the whole tooth now is so short that the large masseters still exert a strong and less oblique pressure upon the third molars which are consequently still of fair size, although the first molars, which are in the position of greatest vertical pressure, have now become dominant.

"From these and similar considerations I should expect that in *Propliopithecus*, from the small size of m_3, the temporals would be relatively small, while from the vertical position of the canine and massive horizontal ramus the masseters ought to be powerful. In *Dryopithecus fontani* the temporal muscles would be only less developed than those of the gorilla, while the massive symphysis and deep horizontal ramus indicate that the masseters also were powerful.

"In conclusion I am unable to accept Dr. Pilgrim's view (*op. cit.*, pl. 4) that the gorilla and chimpanzee have been derived from none of the six known Indian and European species of *Dryopithecus* but trace their origin on separate parallel lines to an unknown proto-anthropoid stock that lived somewhere far back in the Lower Miocene. Such a view may possibly prove to be true; but before assuming it, what characters definitely exclude *D. chinjiensis*, *D. punjabicus*, and *D. fontani* from at least very close kinship with the true ancestors of both the gorilla and the chimpanzee? While differences between the Miocene and modern genera are striking, my difficulty in fact is to find provedly aberrant characters which will definitely and positively exclude these forms from such ancestry. According to Dr. Pilgrim the cleft between gorilla and chimpanzee is so great that the latter is very widely removed from the known species of *Dryopithecus* in the Upper Miocene of India. But to me, after comparing repeatedly the Indian types with the gorilla and chimpanzee, the evidences at least of close kinship are of the most convincing character. According to this view the European *D. fontani* may even be directly intermediate between the Asiatic types on the one hand and the modern African gorilla on the other; while the allied *D. rhenanus* may stand nearer to the direct ancestors of the chimpanzee.

"*Dryopithecus rhenanus* (Pohlig). While *D. fontani* is of Upper Miocene age, *D. rhenanus* comes from the Lower Pliocene (Swabian Bohnerz). It is represented chiefly by two upper molars and a number of lower molars, from the Swabian Alps, which have been very carefully figured by Branco (1898, Taf. I, II). According to Abel (1902, p. 2) the real type of the species is a femur from the sands of Eppelsheim, described by Pohlig (1895) as *Paidopithex rhenanus* and by Dubois (1897) as *Pliohylobates eppelsheimensis*. These were later referred by Schlosser (1902), along with the upper and lower molars, to the genus *Dryopithecus*. Abel defines the species

as follows: Molars longer than broad (except the lower m_1), the hypoconulid placed well in toward the center. Basal cingulum as a rule not present, except on the last lower deciduous molar.

"The trigonid basin is represented by a transversely oval pit (fovea anterior) at the front end of the crown, while a similar pit (fovea posterior) at the hinder end lies between the remnant of the posterior cingulum and the ridge connecting the entoconid and the hypoconulid. This ridge is quite prominent in this species and in *D. giganteus*, but not in other species.

"The upper molars are quadritubercular with strong folds and wrinkles. They are distinguished from the upper molars referred to *Dryopithecus punjabicus* by the following characters observed by Pilgrim (1915, p. 20). In the Indian species, 'the breadth index of the molars is greater. The cusps are probably lower. The outer cingulum is less clear. . . . The furrows on the outer cusps cross the edge of the tooth, and so produce in

FIG. 255. COMPARISON OF LEFT UPPER MOLARS. × 3/2

A.—*Griphopithecus suessi*, m^2. After Abel.
B.—*Dryopithecus punjabicus*, m^1. After Pilgrim.
C.—*Dryopithecus rhenanus*, m^1. From a cast of a specimen figured by Branco.
D.—Chimpanzee, m^1. Amer. Mus. Nat. Hist., no. 35,550.
E.—Orang, m^1. Amer. Mus. Nat. Hist., no. 35,549.

side-view a serrated appearance, which seems to be absent from *Dryopithecus rhenanus*.' The patterns of both the upper and the lower molars of *Dryopithecus rhenanus* approach those of the chimpanzee in many characters, except that in the latter the molar crowns are more rounded, less quadrangular; and the third molars are often rounded and more degenerate in form. *D. rhenanus* may therefore represent a closely related if not directly ancestral phylum leading to the Pleistocene and recent chimpanzees."

Neopithecus. (From "Studies on the evolution of the primates," 1916, pp. 310–311.)

"Dr. Schlosser (1902, p. 266) suggests that the age of this specimen may possibly be Upper Pliocene. This genus and species is represented by a third lower molar from the Swabian Bohnerz. It is smaller than any

species of *Dryopithecus* and is distinguished from all other anthropoids by its narrowness, the breadth index being only 75.7, while in *Dryopithecus* the index ranges from 80.1 to 87.4 (Pilgrim). Gaudry suggested that it was a last lower milk molar but this view was vigorously combatted by Schlosser (1901, p. 162), who states that a milk molar may always be recognized by its strongly divergent roots which afford space for the replacing tooth beneath it, and by its thin enamel, the opposite characters being shown in the molar under consideration. Schlosser notes that this tooth has the characters of a permanent m_3, that the posterior root is compressed and prolonged backward, while the median posterior cusp (hypoconulid) is unusually large and forms a third lobe. In the living anthropoids and in man this strong development of the posterior cusp of m_3 is no longer evident, but as it is found in almost all of the more ancient mammals and is present in *Pliopithecus*, the ancestor of the gibbons, its presence in a fossil anthropoid, says Schlosser, is not surprising.

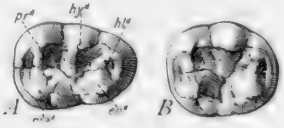


FIG. 256. COMPARISON OF LOWER THIRD MOLARS OF (A) *Neopithecus brancoi* AND (B) *Dryopithecus rhenanus*

A.—Lower third molar of *Neopithecus* (*Anthropodus*) *brancoi* Schlosser. × 3/2. Drawn from a reversed image of a cast of the type, which is a third left lower molar.

B.—Third right lower molar of *Dryopithecus rhenanus*. × 3/1. From a cast of a specimen figured by Branco.

"Under the name *Anthropodus* (which, as noted by Abel, was preoccupied by *Anthropodus* De Lapouge), Dr. Schlosser gave the following generic definition:

'*Anthropodus* n. g. Only lower m_3 known, much longer than broad, without basal cingulum, consisting of five principal cusps, whereof the first inner cusp (metaconid) is higher and larger than the remaining second inner cusp (entoconid). Second outer cusp (hypoconid) and posterior cusp ('mesoconid') alternating; first outer cusp (protoconid) standing only a little further back than the first inner cusp (metaconid). Secondary intermediate cusps present behind metaconid and between entoconid and mesoconid. Cusps provided with enamel grooves running toward the midline—one for each cusp except the metaconid which has three grooves. Peculiar topography (Sonstiges Relief): furrows and grooves weakly developed. Posterior root of m_3, as a result of the talonid-like extension of m_3, strongly extended posteriorly.'

"As specific characters Dr. Schlosser gives the dimensions of m_3 (length 10.3, greatest breadth 7.8, height of the metaconid 5.3) and the estimated measurement of the three lower molars (35 mm.) and of the premolars and molars (46–48 mm.).

'From the corresponding molars of *Dryopithecus*,' that of the present genus,' continues Dr. Schlosser, 'is distinguished by its relatively slight breadth, by the relative lowness of the several cusps, by the strong development of the mesoconid, by the weakness of the enamel wrinkles and above all by the weak relief of its grinding surface; although the course of the principal enamel furrows is essentially the same in the two genera. At first sight it is much like a human tooth, but the latter is very much shorter and wider, with more massive higher cusps, and consequently deeper insinking of the middle of the crown; finally the enamel furrows and grooves in man are decidedly coarser and the whole relief of the crown somewhat more complicated and irregular. In all these details, except the less strongly developed cusps, *Anthropodus* is more primitive than either *Dryopithecus* or *Homo*. The origin of *Anthropodus*,' continues Schlosser (p. 267) 'is still obscure; the only certainty is that it is nearly related to *Dryopithecus*. It differs from *Pliopithecus* in the more complicated pattern of the crown through the appearance of enamel foldings and also in the disappearance of the basal cingulum; it is, however, more primitive than *Pliopithecus* in the posterior elongation of m_3.'

"To the writer the type m_3 of the species under consideration presents an underlying resemblance to a certain m_3 of *Dryopithecus rhenanus* of which a photograph is given by Abel (1902, Pl., fig. 4), except that in *Neopithecus* the enamel is covered with coarse grooves, the tooth as a whole is elongate, narrow and the posterior pit is filled up. But, in spite of all efforts, the more precise relationship of *Neopithecus* remains obscure. It may well be a late descendant of some primitive species of *Dryopithecus* that still retained an elongate, narrow m_3. The enamel folds and wrinkles seem to have been acquired independently in all phyla of the man-anthropoid series."

Palæopithecus sivalensis Lydekker. (From "Studies on the evolution of the primates," 1916, pp. 299–301.)

"The type consists of a palate containing the teeth of one side except the incisors. The horizon is the Dhok Pathan zone or Upper Middle Siwaliks, regarded as of Pontian or Lower Pliocene age. Lydekker referred this specimen to a new genus *Palæopithecus* in 1879, but later (1886, p. 3) came to the conclusion that it was 'an ape generally distinct from both

Gorilla and *Simia*, but so close to *Troglodytes* [the chimpanzee] as to leave little doubt as to its identity—an identity rendered the more probable by the occurrence of *Cynocephalus* in the same region. In those respects in which the Siwalik *Troglodytes* differs from the existing African species

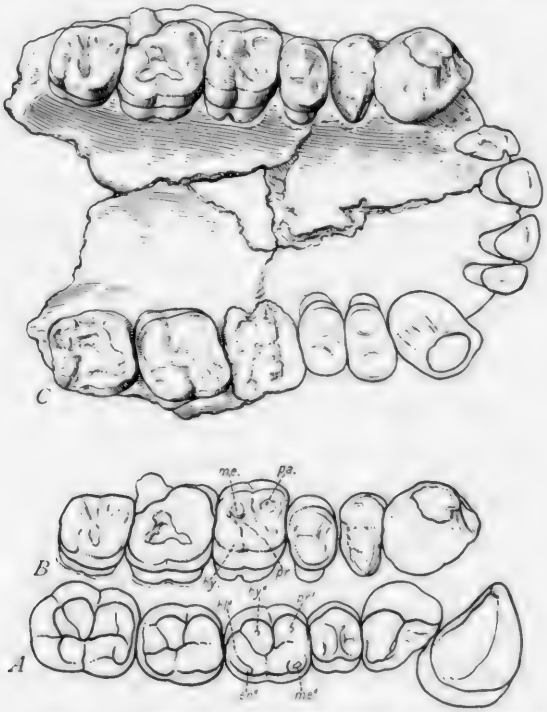


FIG. 257. TEETH OF *Palæopithecus* AND OF *Sivapithecus*

C.—Upper teeth and palate of *Palæopithecus sivalensis*. After Dubois. × 1.
B.—Upper teeth of *Palæopithecus*.
A.—Lower teeth of *Sivapithecus*.
The canine, anterior premolar, and third molar of *Sivapithecus* belong to different individuals. The relations between the lower teeth of *Sivapithecus* and the upper teeth of *Palæopithecus* seem hardly close enough to be indicative of generic affinity.

it shows in a still more marked degree the approach to the human type of dentition presented by the latter, and serves, in a small degree, to bind still closer the connection between the Simiidæ and the Hominidæ. In the inclination of the two series of cheek teeth and the relative lateral position

of the premolars to the true molars, the genus *Hylobates* makes an approach to the human type which is wanting in all the larger existing Simiidæ, and it is very noteworthy to find a similar relation obtaining in the Siwalik *Troglodytes*, accompanied by a more human-like structure of the upper premolars.'

"Dubois (1897) dissented from Lydekker's conclusions, gave a corrected figure of the type and concluded that one should rather assign to *Palæopithecus* a position in the family Simiidæ lower than that of any of the four living genera (p. 90); also that the Indian *Palæopithecus* may have been a later member of an older group of anthropoids that included the European Miocene genera *Pliopithecus* and *Dryopithecus*.

"Dr. Pilgrim (1915) gives an extended analysis of the known characters of *Palæopithecus*, in which he lists eleven characters in which the type differs from the chimpanzee, seven in which it differs from man, three which distinguish it from *Dryopithecus*, and so forth. To the reviewer many of the characters which distinguish *Palæopithecus* from both the chimpanzee and the gorilla appear to be simply primitive characters, which may either prove to be characteristic of the Upper Siwalik ancestors of these apes, or may at that time have been retained by *Palæopithecus* as a conservative genus. The narrow palate, relatively small incisors and slightly convergent tooth rows are, for excellent reasons, to be ascribed to the ancestral anthropoids, since the opposite characters are characteristic specializations of all the larger existing Simiidæ. In the existing chimpanzee, which is strongly brachycephalic, the upper cheek teeth are evidently beginning to suffer retrogressive changes such as have been carried to far greater lengths in brachycephalic races of man. Thus, the molars are assuming a rounded or subcircular contour, while the number of internal roots in the molars and of external roots in the premolars is apparently in process of reduction, by coalescence, from two to one. Hence in *Palæopithecus*, a more primitive anthropoid, it is not surprising to find more distinctly quadrilateral molars, with two distinct internal roots, and wider premolars with two distinct external roots.

"Several of the characters in which *Palæopithecus* differs from the chimpanzee bring it closer to the gorilla: here belong the stouter canines, the somewhat higher cusps of the molars, the more quadrilateral molars, the greater width of the anterior premolars. To the reviewer it seems closer to the gorilla notwithstanding the laborious arguments of Dubois and Pilgrim.

"The dentition as a whole is also similar to that of *Dryopithecus punjabicus* from which *Palæopithecus* may well be descended.

"Pilgrim notes that it resembles *Pliopithecus* especially in the width and shortness of the premolars and first molar, the narrow palate and straight tooth-row, the small incisors and general characters of the molars, so that, as already said, Pilgrim and Dubois regard it as a relative of *Pliopithecus*, from which, according to Pilgrim, it is distinguished by its greater size (the tooth row being nearly as long as in a chimpanzee), wrinkling in the enamel and reduction of the internal cingulum. The reviewer, on the other hand, regards the points of resemblance to *Pliopithecus* as all primitive characters.

"*Palæopithecus* also resembles the Lower Siwalik genus *Sivapithecus* Pilgrim (to be noted below) in the general appearance of the molars, with relative width of the molars and anterior premolars, in the height of the cusps, and in the amount and character of the wrinkling of the enamel. Lydekker indeed suggested that the jaw of *Sivapithecus* should be referred to *Palæopithecus*, a suggestion that has not yet been definitely disproved, since Dr. Pilgrim's principal objection to it is the assumed wide difference in the front part of the lower jaw in *Palæopithecus* and *Sivapithecus;* but this difference does not exist, if the reviewer's restoration of *Sivapithecus* is more correct than that of Dr. Pilgrim.

"In brief I think that Dubois and Pilgrim have largely misinterpreted the relationships of *Palæopithecus* and that it is quite close to the ancestor of the gorilla, from which it differs only in primitive characters."

The chimpanzee. (From "Studies on the evolution of the primates," 1916, p. 275.)

"The head of the chimpanzee is considerably longer than that of the orang; the most prominent feature in the top view (*fig. 259*) is the extreme protuberance of the orbits and the outgrowth of bony ridges between, above and outside of the orbits. As in the gibbon all these outgrowths are connected with the forward extension and increase of the insertion-areas of the temporal and masseter muscles. The protrusion of the orbits and the development of orbital ridges may be regarded as part of the specialization for frugivorous diet, along with the deepening of the jaws. The sagittal crest of the males is apparently secondary.

"The upper molars (*figs. 255, 259*) clearly retain the sharp V-like ridges of the primitive tritubercular pattern, but they add thereto a poorly developed posterior ridge running from the enlarged hypocone to the metacone. There is a decided tendency to divide the internal root into an anterior and posterior moiety, or rather, the formerly distinct roots may be in course of coalescing. The lower molars (*figs. 252 (C) and 280*) exhibit

the four main cusps and the postero-median cusps which are characteristic of the great apes and man, and in the pattern of their crowns they distantly approach the human type, although the anteroposterior diameter is still greater and the posterior moiety of the crowns not expanded. Traces of the primitive cross-ridges (protolophid, metalophid) are retained. The third upper and lower molars are somewhat reduced in size and degenerate in form. The rounded contour of the upper molars is correlated with the

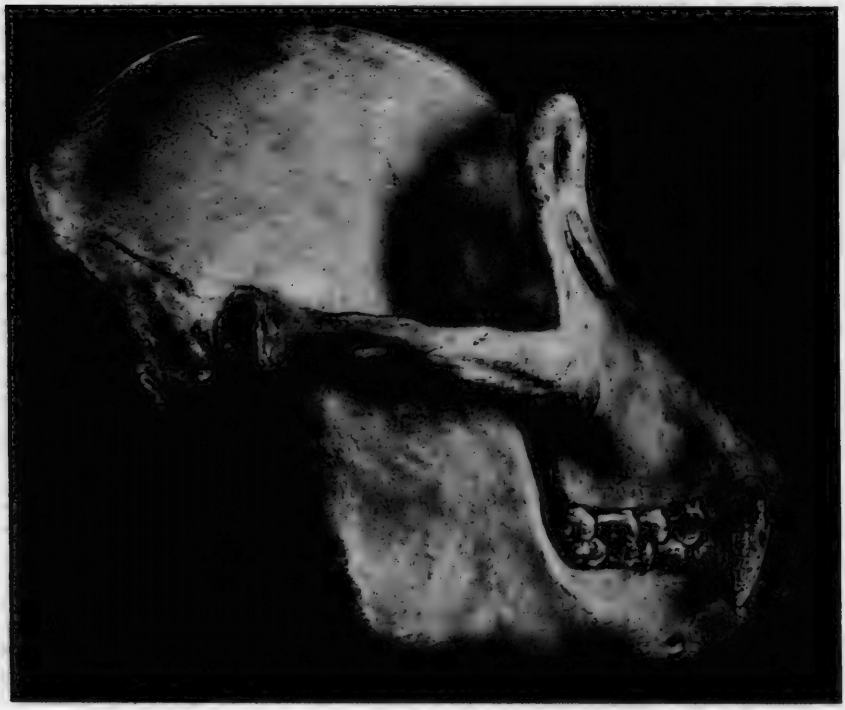


FIG. 258. SKULL OF CHIMPANZEE, *Pan vellerosus*. × 4/5. AFTER ELLIOT

partly oblique, partly rotary excursion of the mandible. The molar crowns are coarsely wrinkled, the cusps being lower than in the gorilla. The upper premolars (*fig. 258*) are comparatively small and are prominently bicuspid. The lower premolars are of normal anthropoid type, but are under the average size. The opposite premolar-molar rows are nearly parallel in the lower jaw but diverge in the upper jaw of old males. The canines form stout tusks. The anterior upper incisors are extremely wide with large wrinkled crowns. The muzzle as a whole is massive."

FIG. 259. SKULL OF CHIMPANZEE, *Pan vellerosus*. × 4/5. AFTER ELLIOT

FIG. 260. *Gorilla gorilla*. × 2/5. AFTER ELLIOT

The gorilla. (From "Studies on the evolution of the primates," 1916, pp. 276–277.)

"The gorilla carries to the logical extreme the frugivorous and fighting specializations which are foreshadowed in the chimpanzee. The head is lengthened by the forward growth of the muzzle and by the extreme backward growth of the skull-top. Thus the gorilla skull, to a certain extent, parallels that of the baboons. The supraorbital protrusion is now extreme. The secondary sagittal crest and widely flaring occipital crests attain an excessive development in old males, and are conditioned by the massive size of the muscles of the jaws and neck.

"The canines form great tusks and hence the muzzle and lower jaw are very wide in front, and the opposite premolar-molar series are parallel or diverge anteriorly. The palate and basis cranii also reflect these swine-like adaptations. All these specializations are either absent or feebly developed in the females and young and may be looked upon as comparatively recent acquisitions which disguise the underlying similarity to the chimpanzee skull. The incisors are relatively narrow. The upper premolars are wide; the front lower premolar, in correlation with the tusk-like form of the upper canine, is shaped somewhat like that of a baboon, with a sloping well-worn antero-external face. The molars all have conical cusps which are higher than in the other anthropoids and are less complicated by secondary folds and wrinkles. In correlation with the marked anteroposterior elongation of the head the upper molars are now divided into large anterior and smaller posterior moieties, but clear traces of the original trigonal pattern remain. The lower molars are also more elongate than those of the chimpanzee. The protoconid and metaconid are connected by a cross crest (protolophid) which fits between two adjacent upper molars. The fundamental pattern of all the premolars and molars are those seen in all anthropoids. The lower jaw is very massive with a long stout horizontal ramus and broad ascending ramus.

"Thus the fundamental resemblances to the human skull are largely disguised in the male gorilla, which is distinguished by the great tusks and massive cheek teeth, the divergent tooth rows, the baboon-like muzzle and protruding orbits, in contrast with the opposite specializations in man. The young female gorilla, on the other hand, except in the dentition, more distinctly approaches the human type than any other anthropoid, in all views of the skull (profile, front, top and back), in the interior and base of the braincase, and in the details of the tympano-petrosal region."

FIG. 261. *Pseudogorilla mayema* ♀. × 1/2. AFTER ELLIOT

FIG. 262. *Pseudogorilla mayema* ♀. × 1/2 AFTER ELLIOT

Relationship of the chimpanzee and the gorilla. The prolonged and thorough anatomical investigations of Keith (1915) have demonstrated the relatively close relationship to each other of these two genera (*Pan*, *Gorilla*), which were formerly placed in a single genus, *Troglodytes*. But although certain species of chimpanzee approach the gorillas in some characters it is probable that the two genera have been separated since Miocene times, because one species of *Dryopithecus*, *D. chinjiensis*, seems to be tending in the direction of the gorilla, while another, *D. giganteus*, as well as *D. rhenanus*, appear to be more nearly related to the chimpanzee.

THE PILTDOWN PROBLEM

Stated in the briefest terms this problem is as follows: In 1911, Sir Charles Dawson discovered some fragmentary human and other ancient animal remains in a gravel pit on Piltdown Common, Fletching, in Sussex, England, the human remains being described by Smith Woodward (1913) under the name of *Eoanthropus dawsoni*. The age of the gravel bed has been much disputed, some holding that it was of Upper Pliocene age, but the majority regard it as of Pleistocene age.

The fragmentary pieces of the skull are admitted by all to be of human type. The lower jaw fragment found near the skull in many respects resembles that of a chimpanzee, so that several investigators deny that it belongs with the human skull. Gerrit S. Miller (1915), who has made a very careful study of the subject, concludes that the lower jaw represents a Pleistocene species of chimpanzee which he has named *Pan vetus*. Subsequently a canine tooth was found in the same locality, but opinion is divided whether it is an upper or a lower canine, the writer and Miller holding that it is an upper. Smith Woodward, Pycraft (1917), Elliot Smith, Keith, and most British authors, adhere to the view that the jaw belongs with the skull, while Miller has published a second paper (1918) supporting his contention (which is accepted by many Americans, including the writer) that the weight of evidence up to the present time favors the conclusion that the jaw belonged to a chimpanzee. Smith Woodward (1917) has discovered in another locality, but in the same

geological formation, a couple of fragments of another skull and a lower molar, and he regards these remains as affording decisive evidence in favor of the original association of the Piltdown jaw with the skull. But others doubt whether the new lower molar is really conspecific with the original Piltdown jaw, as it is of definitely human type.

In my "Studies on the evolution of the primates," 1916, pp. 313–320, the Piltdown problem was discussed as follows:

"In an earlier paper (1914) I have reviewed the controversy over the Piltdown remains (*Eoanthropus dawsoni*), emphasizing the entirely human character of the braincase, the essentially ape-like character of the lower jaw and teeth and the doubt as to their association already expressed by several authors. With some doubts, which were even more strongly felt by my colleague, Dr. Matthew, I was led to accept provisionally the association of the jaw with the skull, chiefly because the jaw is stated to have been found within a yard of the point where a piece of the occiput was discovered, and at precisely the same level. In this connection I said (*op. cit.*, p. 194) that 'fossil remains of anthropoids of any age have hitherto been exceedingly rare, and the chances that a jaw of a hitherto unknown type of ape should be washed into the same gravel bed with a human skull of conformable size, and that both should become mineralized in the same manner and degree, may be regarded as extremely small.' The chances of such a coincidence occurring were, no doubt, extremely small, but nevertheless the event must have happened, for I consider that Miller (1915) has practically demonstrated that the Piltdown lower jaw represents a Pleistocene species of chimpanzee and that it did not belong with the associated braincase.

"In all views of the jaw—from beneath, from above, from the inner side and from the outer side—it is generically identical with the aged specimens of *Pan* figured by Miller (1915, pls. 1, 2). Every curve and contour in these chimpanzees is followed with minor variations in the Pleistocene jaw. Dr. Woodward's own comparative figures (1914, p. 317) of the symphysial region of *Eoanthropus* and other anthropoids, as well as his later figures (1915, pp. 16–21) of three views of the jaw, all show how close this jaw is to that of a female chimpanzee and how widely different it is from that of *Homo heidelbergensis*. And not one of the characters of the jaw and teeth, as most ably analysed by Professor Keith (1915, pp. 430–478) establish a generic difference from the chimpanzee.

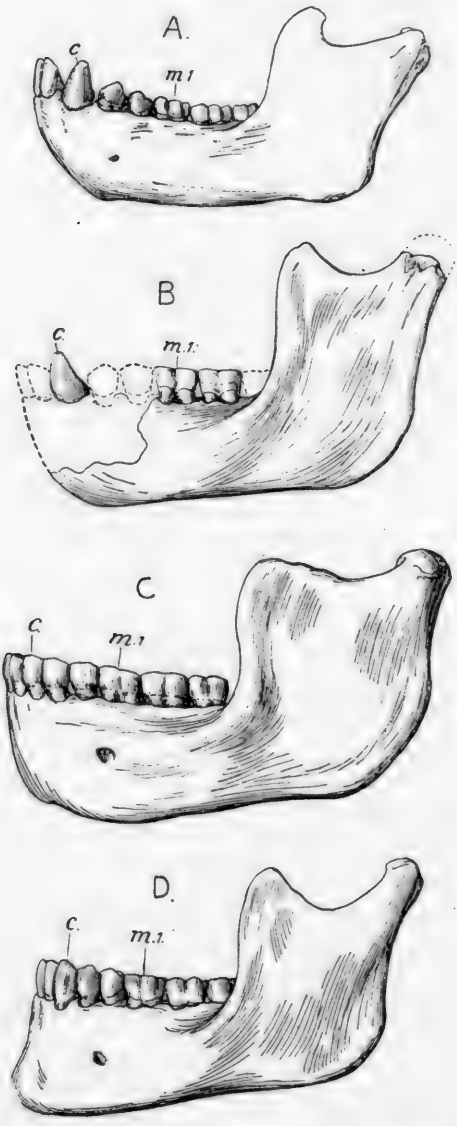


FIG. 263. COMPARATIVE SERIES: LOWER JAWS. × 1/2. AFTER SMITH WOODWARD

A.—Modern chimpanzee.
B.—Piltdown jaw.
C.—Heidelberg jaw.
D.—Modern man

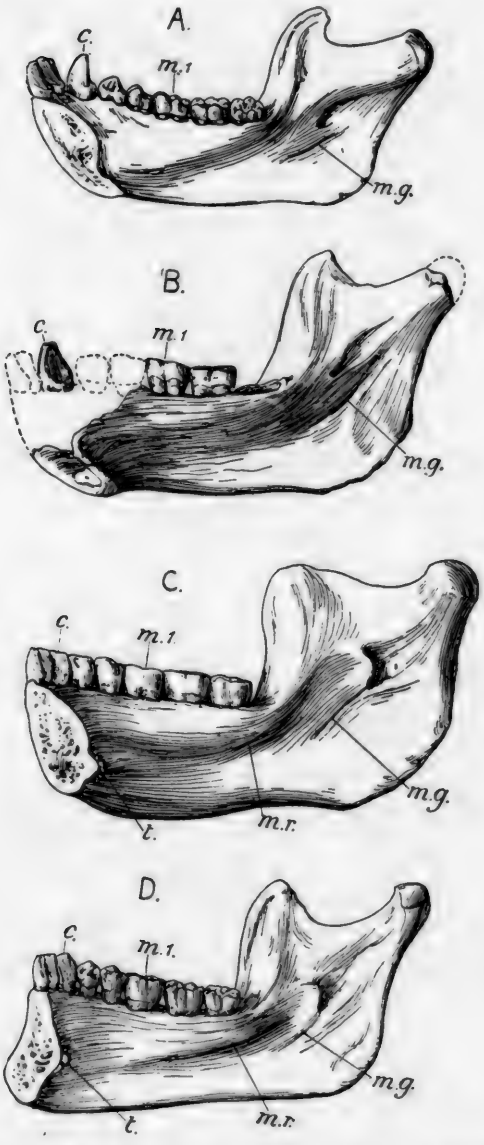


FIG. 264. COMPARATIVE SERIES: LOWER JAWS, MEDIAL VIEW OF RIGHT HALF. × 1/2.
AFTER SMITH WOODWARD

t., genial tubercles; *m.g.*, mylohyoid groove; *m.r.*, mylohyoid ridge

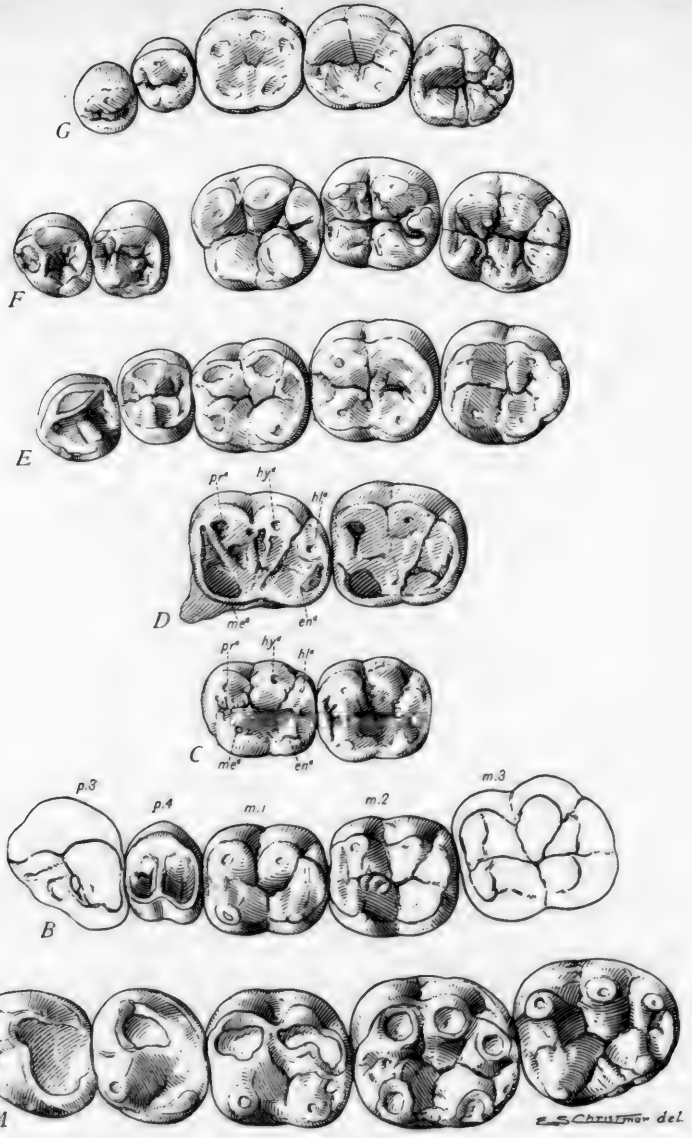


FIG. 265. COMPARATIVE SERIES: RIGHT LOWER PREMOLAR-MOLAR SERIES OF PRIMITIVE MEN AND OF ANTHROPOIDS. CROWN VIEWS. × *circa* 3/2

A.—*Gorilla* sp.

B.—*Sivapithecus indicus*. After Pilgrim.

C.—*Pan* sp. Much worn molars of an old chimpanzee. After Miller.

D.—*Pan vetus*. Much worn molars of the Piltdown mandible; from a photograph published by Smith Woodward (× 3/2 +).

E.—*Homo heidelbergensis*. From a photograph published by Schoetensack.

F.—*Homo sapiens*. Molars of an old female Australian black. Premolars of a male negro.

G.—*Homo sapiens*. Lower premolar-molar series of a Strandlooper Bushman. (Gift of Dr. R. Broom.)

From this series it appears that Miller is well warranted in stating that the Piltdown molars are generically referable to *Pan* rather than to *Homo*.

"The two molar teeth, although greatly worn, show the primitive *Dryopithecus* pattern, which is disguised in all the Hominidæ; the molars appear to agree generically with those of the very old female chimpanzees figured by Miller (*op. cit.*, pl. 2, figs. 2″, 1″, 4). They differ from all human molars that I have seen in being relatively long and narrow and in having the posterior moiety less widened transversely. From the molars of *Homo*

FIG. 266. COMPARATIVE SERIES: TEMPORAL BONES OF (A) THE PILTDOWN SKULL, (B) A NEGRO, AND (C) A FEMALE ORANG. × 2/3

ar.e., articular eminence (for lower jaw); *c.c.*, carotid canal; *e.a.m.*, external auditory meatus; *g.s.*, glenoid socket; *pet.*, petrous bone; *st.*, pit for styloid process; *t.p.*, tympanic plate; *z*, root of zygomatic arch.

heidelbergensis they differ in the same characters, although in somewhat less degree. Also m_1 is a large, wide, well-rounded tooth, which is displaced internally and has its long axis turned more or less inward at the front end, in conformity with the inward sweep of the mandible.

"The completely human character of the glenoid region, and the complete absence of simian features both in this region and in the region of the temporal muscle area, offered an insuperable difficulty, as long as one accepted the supposed association of the jaw with the skull. By all well-founded analogies a true link between the Simiidæ and Hominidæ should have more intermediate characters in both jaw and temporal region; but, as fully expounded by Dr. Miller (*op. cit.*, pp. 14–18), the whole conformation of this region in the Piltdown skull demands a human or subhuman

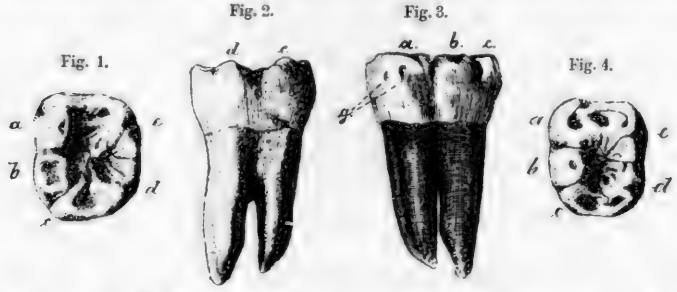


FIG. 267. LOWER LEFT FIRST MOLAR (*figs 1–3*) FROM THE DILUVIUM AT TAUBACH NEAR WEIMAR. AFTER NEHRING. ABOUT 3/2 NATURAL SIZE

1, crown view; 2, lingual side; 3, labial side; 4, crown view of m_1 of a modern chimpanzee

Miller remarks that this tooth resembles the first lower molar of the Piltdown mandible and likewise represents a Pleistocene species of chimpanzee. Nehring himself noted its strong resemblance to a chimpanzee molar, but in spite of that referred it to *Homo*.

lower jaw, while the anthropoid jaw demands anthropoid glenoid and temporal regions.

"Now that this anomalous composite called *Eoanthropus* has been resolved into its diverse elements we realize again that the transformation of the Simiidæ into the Hominidæ took place at a much earlier period; and that the entirely human dentition of *Homo heidelbergensis* shows that this transformation was effected long before the mid-Pleistocene; a view which has been strongly urged by Professor Keith, but upon other grounds.

"If the Piltdown skull, which is entirely human, bore a human jaw, as now seems likely, then there is no necessity for pushing the point of divergence of *Eoanthropus dawsoni* and *Homo* far back into the Lower Pliocene, as in Professor Keith's diagram (1915, p. 509).

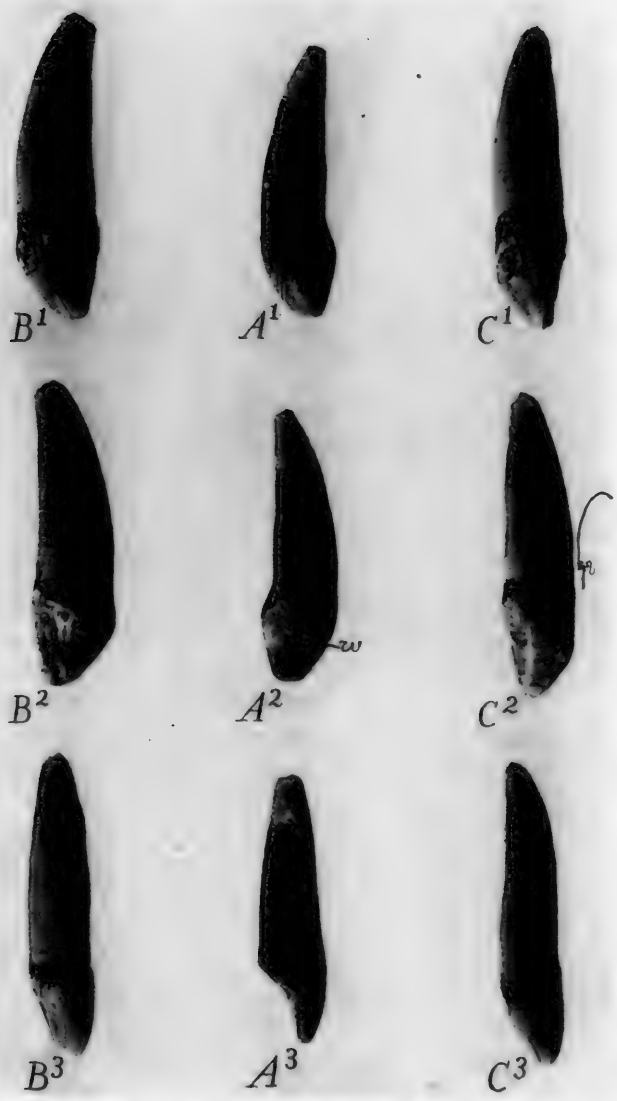


FIG. 268. COMPARATIVE SERIES: (A) CANINE TOOTH (CAST) FOUND AT PILTDOWN IN COMPARISON WITH (B) THE LEFT UPPER CANINE AND (C) THE RIGHT LOWER CANINE OF A FEMALE ORANG. × 1

The lower canine is turned upside down to facilitate comparison with the others. In A the tip of the root is restored.

A^1, B^1, C^1, seen from the outer or labial side.

A^2, B^2, C^2, seen from the inner or lingual side; *w*, worn surface.

A^3, B^3, C^3, seen from the front, or antero-internally.

"The persistence of one of the great apes in the Pleistocene of Europe, as a survivor of the *Dryopithecus* group of the Upper Miocene and Pliocene. is analogous with the persistence in the same region of hippopotamus and other forms at present confined to the tropics. The fact that the Pleistocene species is distinguished from the modern type by a somewhat more robust mandible and larger molar teeth also finds precedents among other mammalian phyla.

"As to the canine tooth: in my earlier paper I recorded the observation of Mr. A. E. Anderson, that this tooth agreed better with the left upper canine of apes than with the right lower one, as originally identified by Dr. Smith Woodward. I was at that time not entirely convinced of this identification, but its correctness seems to have been confirmed by Dr. Miller (1915, p. 12) who finds left upper canines of aged female chimpanzees which closely approximate the Piltdown canine both in form and in the manner of wearing down. I also consider the resemblances to the right lower milk-canine of man, noted by Dr. Woodward (1915, p. 22, fig. 9), as not being sufficiently close to be demonstrative of homology."

It is not practicable, within the limits of this review, to follow the subsequent development of the Piltdown problem in its numerous ramifications and detailed discussion. The reader is referred to the recent papers by Pycraft (1917) and by Miller (1918), the latter containing an annotated bibliography of the subject.

The Piltdown problem has bearing on the general subject of the evolution of the human dentition in so far as it raises the question whether the human brain and braincase assumed its distinctive characters at a relatively early period when the jaws and dentition were still ape-like, as maintained by Elliot Smith (1913). Whether or not the Piltdown jaw belongs with the skull, the fact remains that its contained lower molars are in many respects extremely like those of chimpanzees. But these, in turn, are closely related in pattern to primitive human molars; and the whole Piltdown controversy serves to emphasize not only the fundamental agreements but even the numerous special resemblances in structure of the jaws and teeth of chimpanzees and men.

THE PITHECANTHROPUS PROBLEM

The celebrated fossils discovered in Java by Dubois were described by him in 1892 under the name of *Pithecanthropus erectus*. The

remains were not all found in one spot but were scattered along the course of an ancient stream bed. Although some authorities have doubted the association of skull-top, femur and molars, the majority have accepted Dubois's view that all the remains belonged to one skeleton which had become broken up and distributed by stream action. The geological horizon is uncertain. It was originally thought to be Upper Pliocene from the character of the fossil mammals found in the same formation, but later investigators incline to regard it as of Pleistocene age. The skull-top resembles in general that of a

FIG. 269. COMPARATIVE SERIES: RIGHT UPPER THIRD MOLAR REFERRED BY DUBOIS TO *Pithecanthropus* (C^1) IN COMPARISON WITH VARIOUS HUMAN AND ANTHROPOID TYPES. ALL FIGURES × 3/2

A.—*Dryopithecus punjabicus*, referred specimen. After Pilgrim.
B.—Modern orang.
C^1.—*Pithecanthropus erectus*. Cast of referred specimen (m^3, right).
C^2.—*Pithecanthropus erectus*. Cast of a second referred specimen (m^2, left).
D.—*Homo sapiens*. Australian black (♀).
E.—*Homo sapiens*. Kaffir.
F.—*Homo sapiens*. Brachycephalic Caucasian.

gibbon but it is of human size and the braincase was more voluminous than that of any other known anthropoid. The femur much resembles that of modern men and its form implies an upright gait.[3]

The upper molars represent m^2 of the left and m^3 of the right side. They are distinguished by their very large size and strongly divergent roots. The third upper molar looks as if it might be an enlarged

[3] It is possible that the upright gait was early acquired by the pre-human stock. See below, Part V (JOURNAL OF DENTAL RESEARCH, 1921, iii; March issue).

derivative of a third molar of *Dryopithecus* type (*fig. 269*). It is distinguished by the weak development or absence of the metacone, which is confluent with the general outer rim of the crown. A cast of the second upper molar was erroneously identified by me (1916, p. 320) as a third, but Dr. Dubois has kindly informed me that the original bears a distinct pressure scar on its posterior border which shows that there was a tooth behind it. Moreover this tooth is somewhat more quadrate than the third molar of the opposite side and is far from being a reversed duplicate of that tooth. As a second upper molar it is remarkable for the pronounced reduction in size of the posterior moiety of the crown, including the metacone and the hypocone; the reduction of the metacone is concomitant with a buccal protrusion of the large paracone and a pronounced bucco-lingual slope of the outer border of the crown. The reduction of the hypocone and metacone are a result of degenerative processes in the dentition of the most advanced and presumably late races of man, and their presence at this relatively early period in *Pithecanthropus* tends to remove that genus from the line of ascent leading to later human races. The molar teeth, while of subhuman type, differ in their details from any others known to me.

The association of gibbon-like skull-top, modernized human femur and subhuman upper molars with reduced posterior moiety, if correctly assigned to one animal, may perhaps define *Pithecanthropus* as an early side branch of the Hominidæ, which had already been driven southward away from the primitive center of dispersal in Central Asia, by the pressure of higher races. But whatever its more precise systematic and phylogenetic position, *Pithecanthropus*, or even its constituent parts, the skull-top, the femur and the molars, severally and collectively testify to the close relationship of the late Tertiary anthropoids with the Pleistocene Hominidæ.

III. SUMMARIES AND CONCLUSIONS FOR PART IV

SUMMARY, BASED CHIEFLY ON DENTAL CHARACTERS, OF THE RISE AND EVOLUTION OF THE ANTHROPOID APES

The accompanying diagram (*fig. 270*), taken from my "Studies on the evolution of the primates," expresses the phylogenetic relation-

ships of the higher primates in so far as I was able to conceive them in 1916. After a careful and as far as possible impartial review of the whole subject, and in the light of recent criticisms and developments, I have to confess that I find but little or nothing to change in this diagram at the present time. In so far as it relates to the origin and rise of the whole catarrhine series, except man, whose origin and

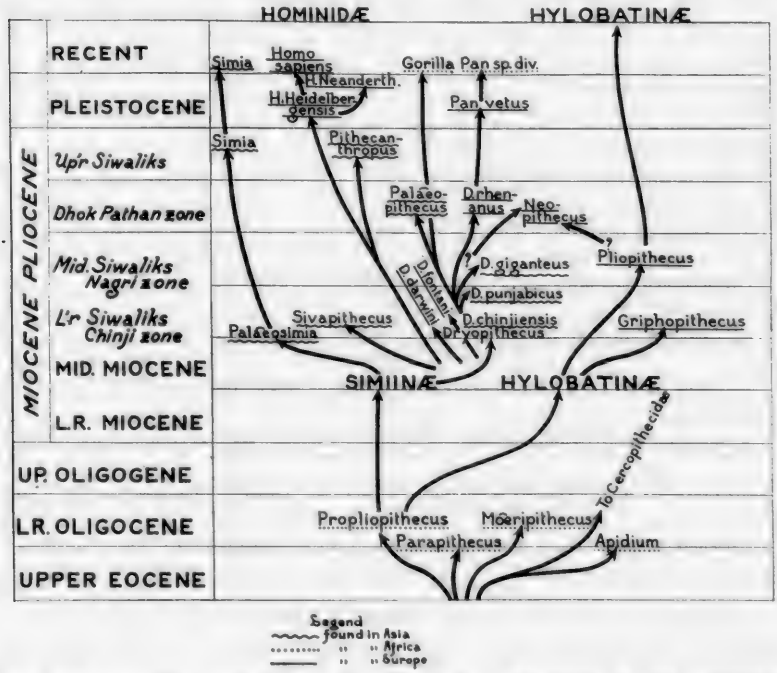


FIG. 270. GEOLOGICAL SUCCESSION AND PROVISIONAL PHYLOGENY OF THE HOMINIDÆ AND SIMIIDÆ, AS INTERPRETED FROM AVAILABLE EVIDENCE BY THE AUTHOR IN 1916

divergence will be discussed below, the conception thus symbolized is outlined in the following pages.

The ancestral stock of the Catarrhinæ may be supposed to have separated from some still undiscovered family of tarsioids at a time considerably before the Lower Oligocene, perhaps the Middle Eocene. The dentition of the ancestral Catarrhinæ, as here conceived, resembled in many respects that of *Necrolemur*, described in Part III, save

that there was no undue specialization of the middle pair of lower incisors.

Parapithecus (*fig. 215*), of the Lower Oligocene of Egypt, may be regarded as a "left-over," or persistently primitive survivor of the ancestral catarrhine stock.

Apidium (*fig. 216*), of the same formation so far as known, appears to represent a similar left-over that gives us a structural stage in the origin of the lower molars of the cercopithecoid branch (family Cercopithecidæ) of the series. These very early entered upon a side path of evolution leading to the specialization of bilophodont upper and lower molars, normally adapted to frugivorous diet; but they retained the more primitive, more quadrupedal mode of progression both in the trees and upon the ground.

The anthropoid-man group of the Catarrhinæ, while early acquiring a new mode of locomotion called brachiation, which will be discussed later, avoided a too early specialization of the dentition, conserving the tritubercular ground plan of the upper molars even after the filling out of the postero-internal corner of the crown (by the development of a prominent hypocone) and retaining the prominent hypoconulid in the lower molars, which is of very subordinate value in the cercopithecoids. The upper molars are, then, essentially four-cusped, while the lower molars have five cusps, namely, the proto-, meta-, hypo-, and entoconids, and the prominent hypoconulid, or mesoconid. The latter is at first medial in position on the crown of the tooth, but early tends to shift toward the outer or buccal side. The posterior lower premolars tend to attain the fully bicuspid type, but the anterior premolars, in all the lines in which the upper canines become large, acquired an oblique, sloping, antero-external sectorial face, which articulates with the postero-internal face of the upper canine. The upper canines usually become enlarged and tusk-like, especially in males, but the lower canines are always smaller. The central upper incisors are more or less widened, with a sharp cutting edge, and often with a posterior central ridge and basal cingulum. The upper incisor crowns are often more or less curved or bent upon the roots in accordance with the degree of prognathism and of overbite. The dental arches, while extremely variable in form, tend to be wide in front, especially in forms with much enlarged canines.

The characters of the dentition in anthropoids appear to be adapted to a mixed diet, large fruits being the principal staple, but insects, young birds, etc., being devoured as opportunity affords. A chiefly frugivorous diet, more or less skill in brachiation, and the habit of sitting upright, are not only characteristic of recent anthropoids but may well be ascribed to their Tertiary ancestors, whose scant remains indicate a fundamental similarity to the surviving members of the family.

The oldest known true anthropoid, as we have seen, is *Propliopithecus*, (*fig. 235*), from the Lower Oligocene of Egypt. Although the type and only known specimen consists merely of a part of the left side of the lower jaw containing the canine and complete cheek teeth, its right to be regarded as a true anthropoid is established by its very characteristic dentition, which shows many strong points of resemblance with that of the Pliocene genus, *Pliopithecus* (*fig. 236*). It is thus connected with the ancestry of the modern gibbons and may also stand in the direct line of ascent leading to the higher anthropoids, as suggested by Schlosser. *Propliopithecus* is much more primitive than any other known anthropoid in its very small size, in the lack of furrows and wrinkles on its molar crowns, in the non-laniary form of the canines, and the non-sectorial form of the anterior lower premolars. On these accounts it might even be conceived as an immediate ancestor of man were it not for much other evidence that tends to connect man closely with the later *Dryopithecus* group, especially with the chimpanzee-gorilla branch.

The modern gibbons (*figs. 237–241*), as we saw, are the smallest and in some ways the most primitive of the anthropoids, retaining many characters of a lower grade of organization and thereby structurally allied with the cercopithecoid group, but nevertheless true anthropoids in the form of the molar teeth; specialized in the laniary development of the upper canines, in the sectorial form of the lower premolars and in the elongation and shallowness of the body of the mandible.

There is a long hiatus in our knowledge of the evolution of the anthropoids, extending between the Lower Oligocene and the second half of the Middle Miocene. When therefore we next meet the group, in the Middle Miocene of India and Europe, we find a great

advance toward the modern genera. The three genera and six species so far known from this age are all very much larger than *Propliopithecus*, one of them, *Dryopithecus giganteus* (*fig. 252*), being truly gigantic in size.

Among the Miocene Indian anthropoids, *Palæosimia* (*fig. 242*) is known only from a third upper molar, which, while structurally related to that of *Dryopithecus*, foreshadows the orangs in some respects. As the orangs are in many respects the most specialized members of the family, it seems highly probable that they were among the first to be differentiated from the *Dryopithecus* stem, and *Palæosimia*, although known only from a single tooth, appears to indicate that this separation took place considerably before the Middle Miocene.

The orangs (*figs. 243–246*) have become excessively specialized for arboreal life and have thereby removed themselves widely from the line of human ascent. Their dentition is specialized in the extreme wrinkling of the enamel (which even obscures the primary cusps of the molar crowns) and often in the excessive prognathism of the upper incisors. The living orangs are extremely variable in dental and cranial characters; for example, the central upper incisors of males vary from 8.5 to 16 mm. in width (Hellman, 1920, p. 27).

Sivapithecus (*fig. 247*). This Upper Miocene Indian genus was regarded by its describer, Pilgrim, as standing near to the line of human ascent, a view which possibly may yet be confirmed by future discoveries. Its lower molars have the "*Dryopithecus* pattern," but are relatively short and wide and in that respect approach the human type. The same is also true of the lower premolars. If the lower canine and incisors are rightly associated with it, it is probable that the general form of the jaw and arrangement of the dental arches were not dissimilar in essentials from those of *Dryopithecus*, from some primitive species of which *Sivapithecus* may be regarded as an offshoot.

Sivapithecus is perhaps more progressive than *Dryopithecus* in the loss of the external cingulum on the lower molars, in their greater breadth-index, in the strong divergence of the molar roots, in the probably greater depth of the mandible and in its shorter symphysis; in the marked advance toward the bicuspid type in the posterior lower premolar, and in the nearer approach toward the bicuspid type in the

anterior lower premolar. The third lower molars lack the "sixth cusp," between the hypoconulid and the entoconid, which occurs in certain orangs, in *Dryopithecus chinjiensis*, in *D. punjabicus*, and in many primitive human jaws. In the phylogenetic diagram (*fig. 270*) *Sivapithecus* is provisionally placed as an early offshoot from the *Dryopithecus* stem, intermediate between the *Dryopithecus*-man group and the *Palæosimia*-orang line.

Dryopithecus (*figs. 248–256*). The six species assigned to this genus differ greatly in size and considerably in details, one of them, *D. darwini*, having such a wide and wrinkled m_3 that it may eventually deserve to be set apart as a distinct but related genus. Abel (1902) has noted that this tooth in its whole appearance and size, and in the arrangement and abundant branching of the furrows, suggests the corresponding characters in the men of Krapina, but that it differs from them in the narrowness of the posterior moiety of the crown, a primitive character. These resemblances are naturally not very close or detailed, because *Dryopithecus darwini* (*fig. 253*) is separated from the Krapina men by the vast time interval between the Upper Miocene and the late Pleistocene; nevertheless it affords one of a number of instances in which the jaws and dentition of the Miocene anthropoids were assuming characters favorable for the starting point of lines of evolution tending toward the human grade.

Of the remaining species of *Dryopithecus*, *D. fontani* (*fig. 254*) of Europe is possibly the most primitive, since its lower molars are (a) relatively narrow, (b) increase in antero-posterior length from m_1 to m_3, and (c) retain the external cingulum seen in *Propliopithecus* and *Pliopithecus*. It is the only species in which the lower jaw and all the lower teeth are known. It is evidently much less specialized than the existing organs, chimpanzees and gorillas: the lower incisors and canines are of moderate size, the lower molars exhibit the typical "*Dryopithecus* pattern," with little or no wrinkling of the enamel and with sharp definition of the cusps; the hypoconulid is more central, less lateral in position than in *D. rhenanus* or in *D. giganteus;* and, as Smith Woodward (1914) has shown, it is also more primitive than existing chimpanzees and gorillas in the shortness of the symphyseal ledge of the mandible. For these reasons I have placed *D. fontani* near the base of the *Dryopithecus* series (*fig. 270*).

Dryopithecus chinjiensis (*fig. 249*), from the Middle Miocene of India, is represented by the type, a third lower molar which resembles that of the gorilla, except that it is more primitive in certain respects. It exhibits the "sixth cusp" which is also found in *D. punjabicus*, the gorilla and certain human molars. The species may stand in or near the gorilla line. A referred first lower molar (*fig. 285*) shows the *Dryopithecus* pattern; it is unusually wide across the posterior moiety, thus suggesting a human tooth.

Dryopithecus punjabicus. In this Miocene Indian species the third lower molar (*fig. 250*) is much smaller than that of *D. chinjiensis*, but it nevertheless approaches even more closely the corresponding tooth of the gorilla in the detailed pattern of the crown. The upper molars and premolars (*fig. 251*) referred to this species by Pilgrim are highly important; first, because they afford knowledge of these parts in an Indian species of *Dryopithecus;* secondly, because they resemble the isolated upper molars of the European *D. rhenanus* well enough to make the generic reference of all the Indian species more certain; and finally, because they show a highly significant resemblance to the upper teeth of gorillas and chimpanzees and more remotely to those of primitive men.

Dryopithecus giganteus (*fig. 252*). This relatively enormous third lower molar from the Indian Miocene resembles those of modern chimpanzees except in its more primitive, less wrinkled character.

Dryopithecus rhenanus. The upper (*fig. 255*) and lower molars, (*fig. 256*), and the deciduous last lower molar (*fig. 287*), of this Lower Pliocene species of Europe closely approach those of modern chimpanzees. The third lower molar shows the "fovea anterior" and the "fovea posterior," which are found in some of the Krapina molars; the fovea anterior being merely the vestigial basin of the trigonid and the fovea posterior being the space between the posterior cingulum, the hypoconulid and the entoconid (cf. *D. giganteus*, *fig. 252*). As shown in *fig. 265*, it is possible that *D. rhenanus* stands in or quite near to the line of ascent leading on the one hand to the "Piltdown jaw" (*Pan vetus*) and on the other to the modern chimpanzees of Africa.

Pan vetus (*figs. 263–265*). Assuming provisionally the correctness of Miller's conclusions, the Piltdown jaw represents the survival of

a species of chimpanzee in England, probably in late Pleistocene times, existing there along with other mammals, including man, which had invaded Great Britain by way of a broad land bridge from the continent, and which were related to modern species now inhabiting more southern countries, such as elephants, hippopotami, rhinoceroses, hyenas, lions, etc. To the same or to an allied species of chimpanzee, Miller also provisionally referred the "human" lower molar (*fig. 267*) found in a Pleistocene deposit near Weimar in Germany and described by Nehring in 1895.

Neopithecus (*fig. 256*). The exact systematic and phylogenetic relations of this third lower molar from the Lower Pliocene of Europe remain uncertain. It is remarkably long in proportion to its breadth, thereby differing from all the known species of *Dryopithecus* and *Pliopithecus*, but the crown pattern looks like an elongated derivative of that of m_3 of *Dryopithecus rhenanus*. It shows the "fovea anterior" and "fovea posterior" of that species and other offshoots of the *Dryopithecus* stock. The remarkable contrasts in proportions between the narrow m_3 of *Neopithecus* and the very wide m_3 of *Dryopithecus darwini*, suggest that we may find corresponding differences in the proportions of the entire jaws of these forms; and the further differences in the "*Dryopithecus* pattern" of the lower molars show that there was a wide adaptive radiation of the *Dryopithecus* stock in mid-Tertiary Europe and Asia, of which we have so far obtained only a preliminary suggestion. Notwithstanding the narrowness of the m_3 of *Neopithecus*, it resembles a human tooth to such a degree that Schlosser, a high authority on extinct primates, at first named it "*Anthropodus*," in allusion to its human appearance.

Palæopithecus (*fig. 257*). In this Upper Pliocene descendant of the *Dryopithecus* group (which is known from an imperfect palate with much worn cheek teeth), the upper teeth approach those of the gorilla but are smaller and more primitive in some respects. The premolars and the molars are also fundamentally similar to those of primitive races of men, the most conspicuous difference being that the upper canine is much larger than in man and its apex extends much below the level of the premolars. The canine is also separated from the lateral incisor by a wide diastema for the reception of the lower canine.

Pithecanthropus (*fig. 269*). As noted above, the association of gibbon-like skull top, modernized human femur, and subhuman upper molars with reduced posterior moiety, if all correctly assigned to one animal, may perhaps define *Pithecanthropus* as an early side branch of the Hominidæ, an offshoot of the *Dryopithecus* group, which had early been driven southward away from the primitive dispersal center, in west-central Asia, by the pressure of higher races.

In conclusion, the Tertiary anthropoids are of interest in the present connection because they assuredly afford prehuman stages in the evolution of the dentition. It is true that certain investigators have not recognized their importance, partly because they are so fragmentary; but it must be remembered that the various fragmentary specimens supplement each other in giving us a general idea of the characters of the dentition and jaws. Thus the lower incisors are known in *Parapithecus*, *Pliopithecus*, *Dryopithecus fontani*, and partly in *Sivapithecus;* the upper incisors are known in *Pliopithecus* and partly in *Palæopithecus*. The lower canines are known in *Parapithecus*, *Propliopithecus*, *Pliopithecus*, *Sivapithecus*, *Dryopithecus fontani;* the upper canines only in *Pliopithecus* and *Palæopithecus*. The lower premolars are known in representatives of all the genera except *Palæopithecus*. All three lower molars are known in all the genera except *Palæosimia*. The upper molars are known in *Pliopithecus*, *Dryopithecus*, *Palæopithecus*, and possibly in *Sivapithecus* and *Pithecanthropus*. More or less of the body of the mandible, sometimes with part of the ascending ramus, is known in *Parapithecus*, *Propliopithecus*, *Pliopithecus*, *Sivapithecus*, and *Dryopithecus fontani*. The third lower molar, which is well guarded from disruptive post-mortem agencies by the surrounding bone, is preserved in five of the genera and in all the six species of *Dryopithecus*.

Notwithstanding the warnings of those who cite the principle of "non-correlative evolution" (see Part V), palæontologists have been well repaid by most diligent and minute comparisons of these extinct anthropoid remains with each other and with the corresponding parts of surviving members of the group. From such comparisons the conclusions may be gained, first, *that the mid-Tertiary anthropoids in dental structure fall well within the limits of specialization set by the modern orangs, chimpanzees, and gorillas; secondly,*

that they afford several successive stages of dental evolution, represented especially by Parapithecus, Propliopithecus, and Dryopithecus, beginning with a relatively low, almost tarsioid stage and culminating in the diverse genera of modern anthropoids. The third and most important conclusion, and the one which will encounter the most opposition, is that the same series also lies in or near the line of human ascent. Because these mid-Tertiary primates are named and generally recognized as anthropoids, Wood Jones (1918, p. 40) insists that none of them can be ancestral to man, partly because he, in common with many others, apparently expects the mid-Tertiary ancestors of man to have only recognizably human characters. This matter is so important and so critical a part of our general problem that it must be reserved for special discussion in the succeeding parts of this work. But before this can be done effectively it seems necessary to make a final review and summary of the chief characteristics of the anthropoid dentition, as a whole and in its several parts, bearing in mind the phylogenetic concept outlined in the preceding pages, and setting forth at the same time the broad resemblances and contrasts in dental characters between anthropoids and man.

SUMMARY OF ANTHROPOID DENTAL CHARACTERS, RESEMBLANCES AND CONTRASTS WITH HUMAN CONDITIONS

(1) The dental formulæ, $I\frac{2}{2}\ C\frac{1}{1}\ P\frac{2}{2}\ M\frac{3}{3}$ and $DI\frac{2}{2}\ DC\frac{1}{1}\ DP\frac{2}{2}$, are characteristic of all anthropoids and primitive men; but a fourth molar rather frequently occurs in anthropoids and occasionally in man.

(2) The incisors, excepting the central uppers, are primitively simple pointed teeth, with a basal cingulum. The central upper incisors, both in anthropoids and in men, tend to become wide, and in certain orangs and chimpanzees they finally become excessively large and wide, with crenate or denticulate edges. They often have on the lingual surface a central tubercle confluent with the cingulum. The lower incisors are relatively simple, primitively rather narrow, not greatly expanded or crowded, gently inclined; becoming vertical or even slightly recurved in man. The incisor crowns are often more or less curved or bent upon the roots in accordance with the degree of prognathism and of overbite. Adjacent incisors are primitively

separated from each other, at the base of the crown, and in anthropoids the upper incisors are also usually separated by diastemata from the canines. Diastemata are lost in man, probably in correlation with reduction of canines and increasing verticality of incisors. While their crowns are often in contact at the inner and outer borders, the incisors of anthropoids are not so crowded as to derange the even curve of the incisor arch, as they often are in man.

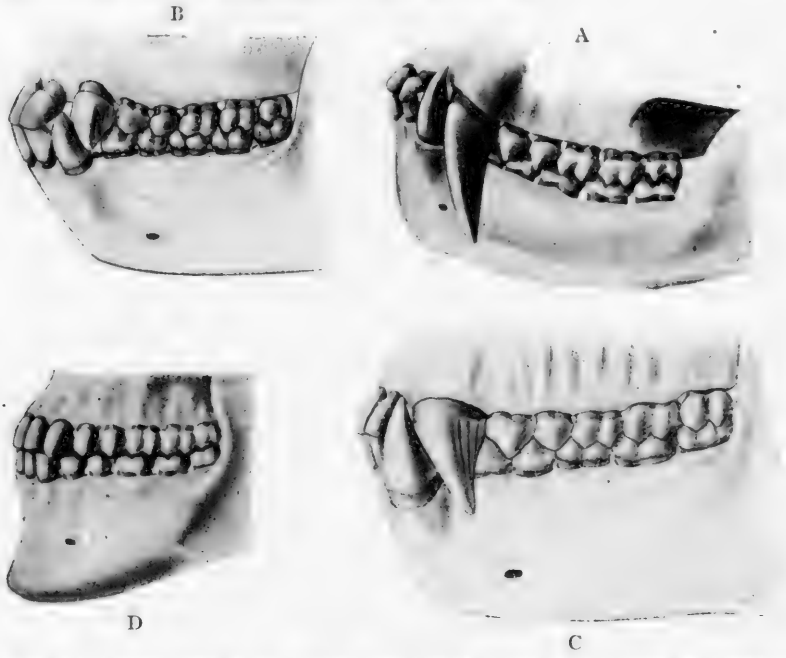


FIG. 271. COMPARATIVE SERIES: UPPER AND LOWER TEETH IN OCCLUSION OF ANTHROPOIDS AND MAN. FROM SALENSKY, AFTER RÖSE

Fig. *A*—Gibbon, *B*—Chimpanzee, *C*—Gorilla, *D*—Man

(3) The canines of males, originally small, are progressively enlarged in all phyla of anthropoids, the upper canines finally becoming sabre-like in the gibbons and tusk-like in the gorilla. Female canines smaller, with lower crowns. The small size and low crown of normal human canines are very probably to some extent retrogressive. Lower canines biting partly in front of uppers, their tips originally received

by diastemata between the lateral upper incisors and the upper canines The upper canines tend to align themselves with the premolars, while the lower canines are rather associated with the lower incisors (*figs. 273, etc.*).

(4) Anterior lower premolars (p_3) originally with simple convex crown and strong internal cingulum; in forms with progressively

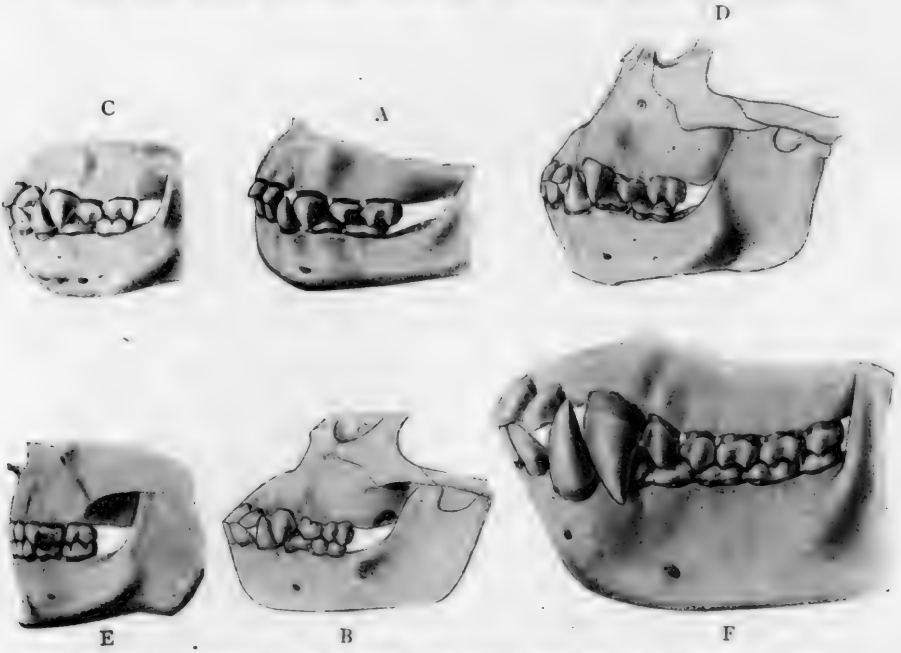


FIG. 272. COMPARATIVE SERIES: UPPER AND LOWER TEETH, IN OCCLUSION, OF ANTHROPOIDS AND MAN. FROM SALENSKY, AFTER RÖSE

A—Gibbon, *B*—Orang, *C*—Chimpanzee, *D*—Gorilla, *E*—Man, *F*—Orang (adult). All except *fig. F* represent the deciduous dentition.

enlarged upper canines the antero-external face tends to become enlarged and more or less sectorial. The stages *Parapithecus*, *Propliopithecus*, *Pliopithecus*, *Hylobates*, show the evolution of the sectorial premolars in the Hylobatinæ (p. 635), while the first two genera and *Dryopithecus* give the origin of the same structure in the higher anthropoids. In *Sivapithecus* (*fig. 247*) the anterior lower premolar,

FIG. 273. GIBBON

FIG. 277. MAN

FIG. 275. CHIMPANZEE

FIG. 276. GORILLA

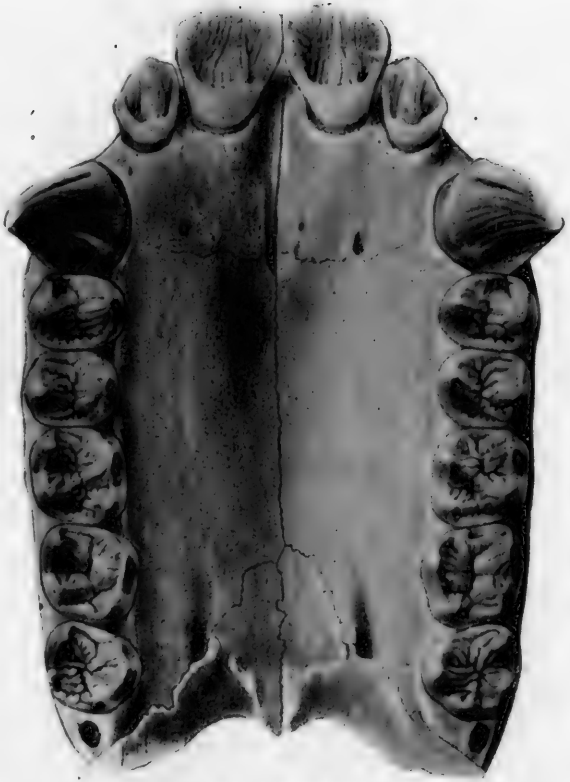


FIG. 274. ORANG

FIGS. 273 TO 277, INCLUSIVE. COMPARATIVE SERIES: UPPER DENTAL ARCHES OF ANTHROPOIDS AND MAN. REARRANGED FROM SALENSKY, AFTER RÖSE

FIG. 278. GIBBON

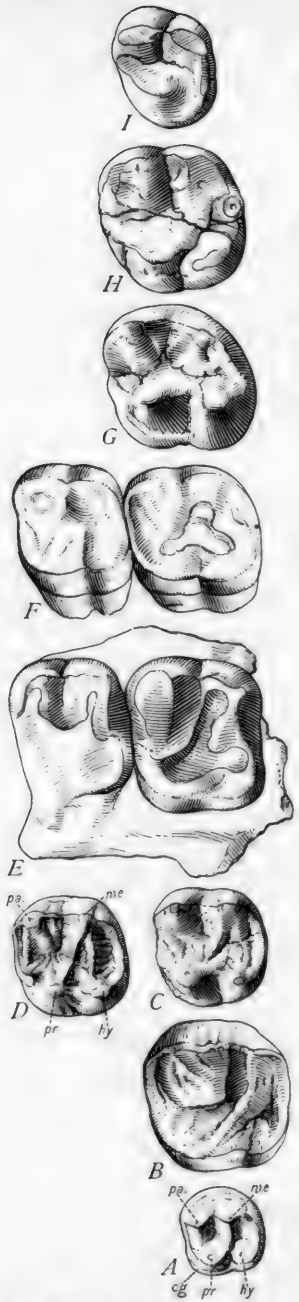
FIG. 280. CHIMPANZEE

FIG. 282. MAN

FIG. 281. GORILLA

FIG. 279. ORANG

FIGS. 278 TO 282, INCLUSIVE. COMPARATIVE SERIES: LOWER DENTAL ARCHES OF ANTHROPOIDS AND MAN. REARRANGED FROM SALENSKY, AFTER RÖSE



I.—*Homo sapiens*, m^2. Brachycephalic Caucasian.

H.—*Homo sapiens*, m^2. Kaffir from South Africa.

G.—*Homo neanderthalensis*, m^2. From the Pleistocene of Krapina. After Gorjanovic-Kramberger.

F.—*Palæopithecus sivalensis*, m^1, m^2, much worn. From the Pliocene of Jobi, India. After Dubois.

E.—*Sivapithecus indicus*. Referred m^1, m^2, much worn. From the Upper Miocene of Haritalyangar, India. After Pilgrim.

D.—*Dryopithecus rhenanus*. Lower Pliocene Bohnerz of the Swabian Alps. From a cast. (m^1.)

C.—*Pan* (*Anthropopithecus*) sp. Recent chimpanzee. (m^1.)

B.—*Dryopithecus punjabicus*, m^2. Upper Miocene of Haritalyangar, India. After Pilgrim.

A.—*Pliopithecus antiquus*, m^2. Upper (?) Miocene of Göriach, Austria. After Hoffman.

FIG. 283. COMPARATIVE SERIES SHOWING CHIEFLY THE SECOND LEFT UPPER MOLAR IN HOMINIDÆ AND TERTIARY ANTHROPOIDS. × 3

In the more primitive members of the series (A–D) the primitive trigon, consisting of the protocone, paracone, and metacone, is reinforced by the large hypocone, which in *Homo neanderthalensis* becomes extremely prominent, the anteroposterior diameter of the crown having meanwhile increased. In the final stage (1), in correlation with the shortening of the whole tooth-row and with the retrogressive character of the dentition, the hypocone disappears, and the small crown assumes a pseudo-tritubercular form.

while possessing some of the sectorial oblique face, is also becoming distinctly bicuspid and its parts may be closely homologized with those in primitive human stages.

(5) Posterior lower premolars (p_4) originally (*Parapithecus*) much like p_3, with high apex, but with low metaconid and low talonid cingulum; in some orangs acquires a submolariform crown with high trigonid and low talonid. In *Sivapithecus* this tooth becomes strongly bicuspid and subhuman in type, but it retains two external roots.

(6) Both upper premolars more or less bicuspid; in *Dryopithecus punjabicus* (*fig. 251*), gorilla and chimpanzee approaching the human type and closely comparable with it in all their parts.

Palæontological experience warrants us in assigning a relatively great phylogenetic value to such resemblances in the premolar patterns of different genera.

(7) First and second upper molars with four cusps and rhomboid contour, the three primary cusps preserving their triangular arrangement and situated at the extreme corners of the tooth. Hardly a trace of the "primary trigon" of Mesozoic mammals is retained, the external cingulum being vestigial or absent and the para- and metacones widely separated, in correlation with the great expansion of the talonid of the lower molars. Paracone usually larger and more protuberant than metacone, the external border of the crown often sloping obliquely inward toward the metacone. Hypocone often on a lower level than the protocone and projecting obliquely backward from the crest connecting the proto- and metacones. Carabelli's cusp (protostyle) not developed but potentially represented[4] by the antero-internal cingulum. No external styles or intermediate conules. Four cusps of varying height and sharpness, highest and sharpest in the gorilla, lowest in the orang. Surface of enamel more (orang) or less (gorilla) furrowed and wrinkled. All the above-named characters of the first and second upper molars are retained in primitive human dentitions.

(8) Third upper molar of varying size and form, the posterior moiety reduced, the hypocone rarely large or protuberant.

(9) First and second lower molars with five cusps (the proto-, meta-, hypo-, an entoconid and the hypoconulid) separated by

[4] Except, rarely, in the gibbons.

furrows, the whole constituting the "*Dryopithecus* pattern," which is exhibited with minor modifications by all mid-Tertiary and later anthropoids. An allied and, as I maintain, a derived pattern, is present in primitive Hominidæ (see below). A sixth cusp, on the medial slope of the hypoconulid, between the hypoconulid and the entoconid, present in orangs, in several members of the *Dryopithecus* group and in certain primitive human dentitions. "Fovea anterior" (the reduced basin of the trigonid) and "fovea posterior" (the vestigial

FIG. 284. ANTHROPOID HERITAGE IN THE LOWER MOLAR PATTERN OF MAN

B.—A primitive lower first molar of man, compared with those of two Miocene anthropoids: (A) *Sivapithecus indicus* (drawn from a cast of the type specimen) and (C) *Dryopithecus chinjiensis*. After Pilgrim. All figures × 3/2.

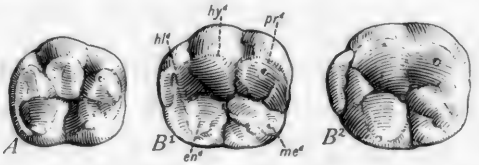


FIG. 285. ANTHROPOID HERITAGE IN THE LOWER MOLAR PATTERN OF MAN (CONTINUED)

Comparison of B¹, B², the fossil human molar (left m_1), discovered by the Selenka expedition near Trinil, Java (A), with the corresponding molar of *Dryopithecus chinjiensis*. B¹, after Deek; B², after Walkhoff; A, after Pilgrim. All figures × 3/2.

depression in front of the posterior cingulum) often present, especially on the third molar. Fovea anterior often, and fovea posterior occasionally, present in primitive human teeth. An external cingulum present in the primitive *Dryopithecus fontani* (*fig. 248*), but lost in most later types. First lower molar more conservative in pattern than second and still more than third. Hypoconid varying in relative size, sometimes [e.g., m_1 of *Dryopithecus chinjiensis* (*fig. 283*), m_3 of *Sivapithecus* (*fig. 247*), many primitive human molars] projecting buccally beyond protoconid, making posterior wider than anterior

moiety of tooth. Hypoconid crowded toward protoconid and entoconid further removed posteriorly from metaconid, as hypoconulid enlarges and shifts from medial to lateral position. In man (*figs. 284, 265*) a secondary enlargement of the entoconid finally brings the furrow between the entoconid and the metaconid into transverse alignment with the furrow between the protoconid and the hypoconid. This process, accompanied by an equalization in size of the four main cusps and by a reduction of the hypoconulid, finally results in a +-shaped pattern of the furrows and a subquadrate contour of the whole tooth (*fig. 265*); but many stages in the evolution of the new pattern from the "*Dryopithecus* pattern" may be traced.

(10) Third lower molar of varying size and form, sometimes (*Neopithecus*, *fig. 256*) long and narrow, sometimes (*Dryopithecus*

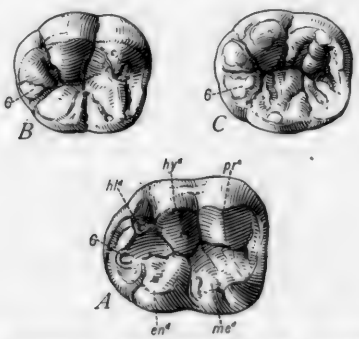


FIG. 286. ANTHROPOID HERITAGE IN THE LOWER MOLAR PATTERN OF MAN (CONTINUED)
ALL FIGURES × 3/2

A.—*Dryopithecus chinjiensis*. Upper Miocene, India. Left m_3. After Pilgrim.
B.—*Homo sapiens*. Left m_1, from the mandible of an Indian child.
C.—*Homo sapiens*. Left m_1 of an adult Australian black (♀).

In the primitive anthropoid (A) the molar crown is elongate, the posterior moiety is not wider than the anterior moiety, and the entoconid is relatively small. In man the opposite proportions are usually found. But the pattern of the crown in primitive human types is fundamentally the same as in *Dryopithecus* and *Sivapithecus*, consisting of five and sometimes six cusps arranged in the same manner. The main furrows also are arranged in much the same way, except that in man, through the great enlargement of the entoconid, the furrow that bounds the hypoconid internally is more or less excluded from contact with the base of the metaconid. In specialized human types the lower molars often lose the hypoconulid and also the sixth cusp (6); they become more or less rounded or subcircular in outline and the main furrows often tend to arrange themselves in a +-shaped, or cruciform pattern.

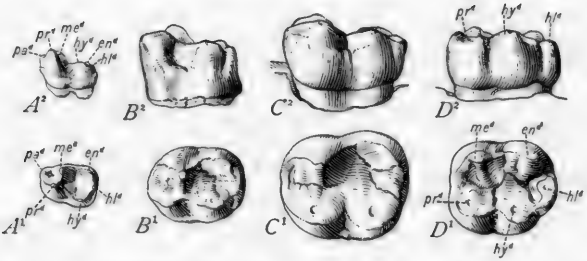


FIG. 287. LOWER POSTERIOR DECIDUOUS PREMOLAR OF (D) *Homo sapiens*, (C) CHIMPANZEE, (B) *Dryopithecus rhenanus* (FROM A CAST); COMPARED WITH (A) A PERMANENT MOLAR OF AN EOCENE TARSIOID (OMOMYS)

A^1, A^2 × 3/1; remaining figures, × 3/2.

In man (D) the tuberculosectorial pattern of the last lower deciduous molar is disguised, but in *Dryopithecus* it was largely retained.

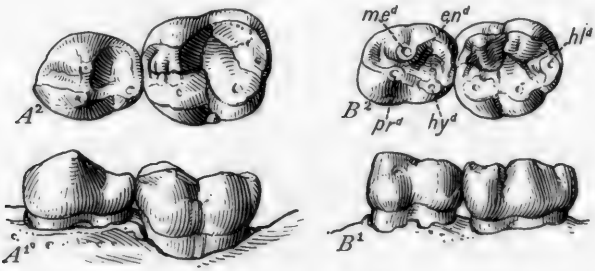


FIG. 288. INFERIOR DECIDUOUS PREMOLARS OF (A^1, A^2) CHIMPANZEE AND OF (B^1; B^2) *Homo sapiens*, SHOWING AGREEMENT IN FUNDAMENTAL PATTERN

As in the case of the upper deciduous molars, the anterior lower one in man is more molariform than in the chimpanzee, which thus retains a more primitive pattern in this tooth, as in others. × 3/2.

FIG. 289. SUPERIOR DECIDUOUS MOLARS OF (A) CHIMPANZEE AND OF (B) *Homo sapiens*, SHOWING AGREEMENT IN FUNDAMENTAL PATTERN

The last deciduous premolar, as in all other mammals, is molariform. × 3/2.

darwini, fig. 253) short, wide and rounded, approaching human types. Sixth cusp and foveæ as described above. Hypoconulid usually more lateral in position than it is in m_1, m_2. Breadth of m_3 across posterior moiety varying with the size and prominence of hypoconid and metaconid, sometimes (*Sivapithecus*, *Dryopithecus chinjiensis*) becoming wider than anterior moiety, as it is often in man.

(11) Deciduous dentition almost unknown in extinct anthropoids, except posterior deciduous molar (dp_4) of *Dryopithecus rhenanus* (*fig. 287*), which is more primitive than that of a modern chimpanzee in retaining more than distinct traces of the primitive tuberculo-sectorial pattern: the trigonid being smaller and higher than the talonid, the hypoconid less protuberant laterally. "*Dryopithecus* pattern" in slightly modified form. Homologous tooth of an Indian child (*fig. 288*) exhibiting similar, but further modified, form of "Dryopithecus pattern," the +-shaped pattern of the permanent molars not being developed; trigonid on same general plane with talonid; hypoconulid large and well defined, metaconid shifted to lingual border of crown, and size of four main cusps subequal.

(12) Posterior upper deciduous premolar molariform (as in most other mammals), with sharply ridged secondary trigon and prominent hypocone. The homologous tooth of man closely similar in general type but with expanded protocone and central fossa.

(13) Anterior lower deciduous molar (dp_3) in recent anthropoids of subsectorial type with more or less flattened antero-external shearing face and low talonid, correlated with more or less compressed and shearing deciduous canines. Corresponding tooth in man of plainly derived pattern but considerably modified: anterior moiety non-sectorial, in correlation with small size of deciduous canines, posterior moiety (talonid) more expanded in correlation with expansion of occluding protocone of posterior upper deciduous molar.

(14) Upper and lower deciduous canines of anthropoids very much smaller, shorter, and less tusk-like than the permanent canines. Deciduous canines of human races normally of same generic type as permanent canines, but plainly representing shortened modifications of the homologous teeth of primitive anthropoids; lower deciduous canines of man set more erectly in mandible than those of anthropoids, their tips not normally exposed laterally in occlusion, but covered

FIG. 291. ORANG

FIG. 290. GIBBON

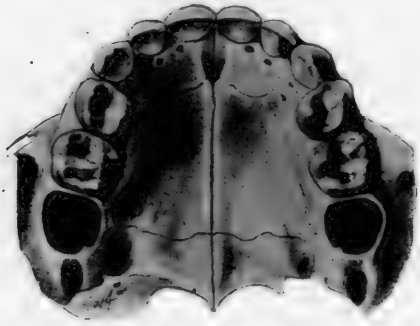


FIG. 294. MAN

FIG. 293. GORILLA

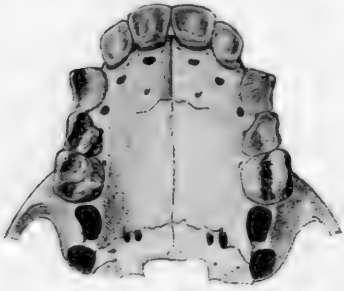


FIG. 292. CHIMPANZEE

FIGS. 290 TO 294, INCLUSIVE. COMPARATIVE SERIES: DECIDUOUS UPPER TEETH OF ANTHROPOIDS AND MAN. REARRANGED FROM SALENSKY, AFTER RÖSE

FIG. 295. GIBBON

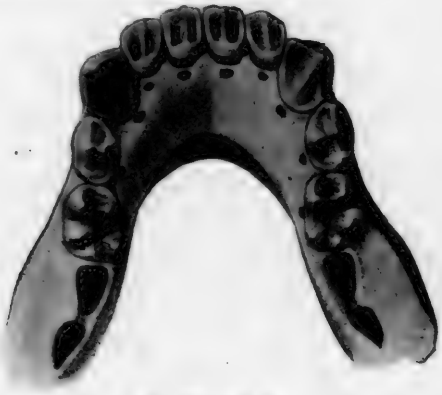


FIG. 296. ORANG

FIG. 299. MAN

FIG. 298. GORILLA

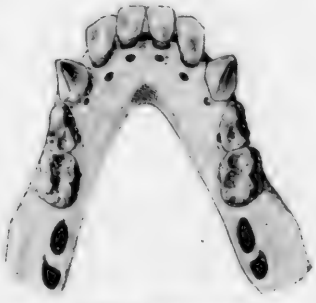


FIG. 297. CHIMPANZEE

FIGS. 295 TO 299, INCLUSIVE. COMPARATIVE SERIES: DECIDUOUS LOWER TEETH. REARRANGED FROM SALENSKY, AFTER RÖSE

by adjacent parts of lateral upper incisor and upper canine; the last two not separated by diastema as they are in anthropoids.

(15) Deciduous incisors of anthropoids and men representing smaller and narrower variants of the homologous permanent incisors of the same genus. Human upper and lower deciduous incisors set more erectly in jaws.

(16) With regard to the chronological order of eruption of the deciduous teeth, in orang, chimpanzee, and gorilla, according to Selenka (1898, pp. 131–141), the deciduous canine is the last to erupt, whereas in man, according to Tomes, the deciduous canines are usually the next to the last.

As to the eruption of the permanent teeth, in anthropoids the permanent canines erupt after the premolars, as in man. In man the second and still more the third molars are delayed in eruption. Otherwise the general order of eruption of both sets is similar in anthropoids and man.

(17) Form of dental arches highly variable in anthropoids (Hellman, 1918, 1919), the upper more than the lower. Lower and probably upper arch pointed in front in the primitive genus *Parapithecus;* opposite rows of upper cheek teeth often strongly divergent in front in highly specialized modern anthropoids with greatly enlarged and tusk-like upper canines. Diastemata behind upper incisors becoming large in forms with tusk-like canines. Opposite rows of lower cheek teeth often more or less parallel.

Upper incisor arches varying more or less with the form and inclination of the incisors and with the varying relations of the centrals and laterals; often pointed in individuals with narrow centrals, wide and flat in those with wide centrals and much protruded laterals. These diverse specializations probably less pronounced in *Dryopithecus rhenanus* than in modern anthropoids.

In man curve of upper dental arch normally more or less elliptical, parabolic or hyperbolic (Leavitt, 1919), but opposite tooth rows more nearly parallel in some extremely dolichocephalic Australians. In general the human dental arch (*figs. 303, 304, 277*) is relatively shorter and wider, and its sides more convergent in front, than those of anthropoids, this condition being associated especially with the increased width of the intercondylar diameter, with the reduction

of the canines and with the more vertical position of the incisors. The human teeth are normally placed in a closed series, the loss of the diastemata being associated with the conditions described above. From very early times there is a marked tendency for the incisors to become crowded so as to overlap at the edges. The lower canines tend to be aligned with the incisor arch, the upper canines with the cheek teeth, the upper canine showing a tendency to become premolariform. The wide differences between modern men and anthropoids in the form of the dental arches (*fig. 277*) is perhaps even greater than the differences between them in the form of the canine teeth. If the Piltdown jaw be associated with the Piltdown skull it affords an example of an anthropoid type of lower dental arch in a human or subhuman race; but the association is denied by some authorities on apparently valid grounds. Again if Smith's restoration (1918) of the upper dental arch of the Talgai man is correct, we have an almost anthropoid form of upper arch in a human skull. But the correctness of this restoration is denied by Hellman, who, after examining the cast of the original, holds that if the canine be put in its right place and the distortion of the tooth rows be corrected, the upper arch will be not very dissimilar to that of the Neanderthaloids. For the present, then, it is conservative to affirm that, with regard to the differences between anthropoids and men in the form of the dental arches, there is as yet no generally accepted palæontological evidence of transitional stages. Nevertheless the comparative anatomical evidence (*e.g., figs. 218, 258, 302*) shows that forwardly diverging tooth-rows are associated with tusk-like canines, long jaws, and other conditions noticed above, while converging tooth-rows are associated with reduced canines, short jaws, and widened intercondylar diameters. In man the great widening of the tongue may also have contributed to the end result.

EVIDENCE OF THE DENTITION AS TO THE PHYLOGENETIC RELATIONSHIPS OF THE SIMIIDÆ WITH THE HOMINIDÆ

In spite of the differences between men and anthropoids in the size of the canines and incisors, and in the form of the dental arches, it is quite obvious from the foregoing review that the resemblances

are far more numerous, detailed and fundamental than the differences, both in the permanent and in the deciduous dentures. Of all known primates the anthropoids stand by far the nearest to man in the totality of their dental characters; the Platyrrhinæ are much further off, while the position of *Tarsius* is extremely remote. The natural assumption that these degrees of resemblance correspond roughly to degrees of kinship would doubtless be denied by Wood Jones, who holds that many of the resemblances of man to the anthropoids have been independently acquired and that man's nearest existing relative is *Tarsius*. But his arguments have been discussed by several eminent authorities and shown to have little weight.[5]

Although some palæontologists, anatomists, and anthropologists may be inclined to discount the phylogenetic value of the numerous resemblances in the dentition between anthropoids and men and to ascribe them largely to "convergence," the resemblances in question are so intimate and fundamental that the case seems rather to fall under a general principle enunciated by Osborn (1908) and familiar to all close students of mammalian phylogeny, namely, that identical characters are often developed by divergent descendants of a common stock. Another applicable principle is that, in general, the more numerous and detailed are the special resemblances between divergent offshoots of a common stock the nearer is the relationship between them; a third is that while *general* resemblances between single parts of the dentition are often produced by convergent evolution in widely different stocks in adaptation to similar habits, *coincident* resemblances in the dental formulæ of both dentures, and in the fundamental plan and even minor details of each tooth, are not found to exist between members of widely unrelated families. In other words a similar "habitus" in parts of the dentition is sometimes assumed by members of different stocks, but on close examination their "heritage" is seen to be different. For example, among the "pseudo-horses," or horse-like litoptern ungulates of the Miocene of Patagonia, the upper molar teeth bear a superficial resemblance to those of *Mesohippus* and other three-toed horses, but the dental formula and the incisor teeth are different, and upon close examination even the patterns of the molars

[5] See a recent discussion of the zoölogical position and relationships of *Tarsius*. *Proceedings of the Zoological Society, of London*, 1920 (Feb.), p. 465.

and premolars, although superficially similar, are seen to differ in certain important diagnostic characters that separate the "pseudo-horses" and their allies from the true horses. When, on the contrary, we compare the dentition as a whole of anthropoids and men we find that they resemble each other in their heritage of ancient common characters but differ widely in their habitus of lately acquired specializations, such as those of the incisor and canine teeth and dental arches.

Most authorities are willing to admit that the anthropoids are the nearest existing relatives of man, although many regard the Hominidæ as an exceedingly ancient stock which may have diverged from the group that gave rise to the Simiidæ in Eocene or even earlier times. *But the conclusion indicated by the foregoing review of the dentition and to which all the rest of my investigations have also led, is that the Hominidæ have been derived from the Dryopithecus group of the Simiidæ in the late Tertiary.* This conclusion is supported by the concurrent testimony of comparative anatomy, which as will presently be shown, points to a very near relationship of the Hominidæ to the gorilla-chimpanzee division of the Simiidæ

In the preceding pages (Part IV) our attention has been focussed first upon the dentition of recent and fossil anthropoids, secondly upon the resemblances and contrasts between the dentition of anthropoids and that of men, and thirdly upon the phylogenetic relationships of the two families, Simiidæ and Hominidæ, in so far as it may be inferred from the foregoing evidence. In Part V we may consider in more detail the dental characters of extinct and recent races of man, dealing again with their resemblances with and differences from the anthropoids, and considering such objections to the foregoing conclusions as are based on the deficiency of palæontological evidence.

(End of Part IV)[6]

[6] See the foot-note on the first page of this part of the review.—(Ed.)

THE ENDOWMENT FUND FOR THE SUPPORT OF THE JOURNAL OF DENTAL RESEARCH

EIGHTH REPORT

WILLIAM J. GIES

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Prophylactic Tooth Powder, Inc., 38 East 61st Street, New York City

A complete list of the contributors to this fund, to the end of the year 1920, is given in the section of general matter, including the title page, for volume II. The first three supplementary lists for 1920 were published on pages 195, 325 and 531 of this volume.

Contributions to this permanent endowment fund, *in any amounts*, are invited from *all who may be interested in the welfare and continuing success of this* JOURNAL.

SCIENTIFIC PROCEEDINGS

OF

DENTAL AND STOMATOLOGICAL SOCIETIES

A LIST OF THE NAMES OF THE ORGANIZATIONS THAT HAVE VOTED TO MAKE THE JOURNAL OF DENTAL RESEARCH THE MEDIUM FOR THE OFFICAL PUBLICATION OF THEIR SCIENTIFIC PROCEEDINGS

(December, 1920)

ASSOCIATION OF THE ALLIED DENTAL SOCIETIES, INC.

AMERICAN ACADEMY OF DENTAL SCIENCE

MASSACHUSETTS DENTAL SOCIETY

HARVARD ODONTOLOGICAL SOCIETY

BOSTON AND TUFTS DENTAL ALUMNI ASSOCIATION

FIRST DISTRICT DENTAL SOCIETY OF THE STATE OF NEW YORK

METROPOLITAN DISTRICT OF THE MASSACHUSETTS DENTAL SOCIETY

HARRIETT NEWELL LOWELL SOCIETY FOR DENTAL RESEARCH, OF THE HARVARD UNIVERSITY DENTAL SCHOOL

SAN FRANCISCO SOCIETY FOR DENTAL RESEARCH

COLORADO SOCIETY OF PERIODONTISTS

AMERICAN ACADEMY OF PERIODONTOLOGY

COLUMBIA UNIVERSITY BIOCHEMICAL ASSOCIATION

In the case of the last named organization, only the dental and stomatological parts of its proceedings will be published in this JOURNAL.

A standing general invitation is extended to dental and stomatological societies, everywhere, to add their names to the above register.

CONTENTS OF THIS NUMBER

Presenting a summary of the titles of the papers, and the names, degrees, and professional relationships of the authors, with abstracts or interpretations of the original matter in each communication.

These abstracts are neither editorials nor criticisms; they do not contain comment beyond the scope of the papers to which they refer. They are intended solely to give the reader a general though clear idea of what the corresponding authors have chiefly to say.

[*This summary of abstracts is reprinted in this issue, with the title page and other introductory matter intended for bound copies of the volume (II) for 1920, so that, in binding the volume, these particular pages (for this number) may be rejected.*]

Papers in the Main Body of this Number

Samuel James Meltzer. In Memoriam 534

We record the recent death of S. J. Meltzer, one of America's most eminent men of science, and an editor, for physiology, of this Journal. The originals of the portrait and signature, on page 534, were selected for our use, at our request, by Dr. Meltzer's son-in-law, Dr. John Auer, one of the editors for pharmacology.—(W. J. G.)

A microscopic study of pulps from infected teeth. By Arthur T. Henrici, M.D., Associate Professor of Bacteriology, and Thomas B. Hartzell, M.D., D.M.D., Assistant Professor of Bacteriology, College of Medicine, University of Minnesota, Minneapolis, Minn. 537

In a previous paper (Journal of Dental Research, 1919, i p. 419), Henrici and Hartzell presented results of bacteriological studies which indicated that, "in nearly one-half the number of cases where (clinically vital) teeth or their investing tissues are infected, bacteria . . . . are already present in the pulp tissues;" and that "the presence of these bacteria in the pulp must be accompanied by some chronic inflammatory changes in the tissues." The present paper describes a continuance of these studies, and presents and illustrates the microscopic findings for pulps from forty-one *clinically vital* teeth, thirteen of which teeth "showed pyorrhea alone, five were invaded by caries without pyorrhea, and twenty-three exhibited evidences of both

caries and pyorrhea." The authors have found evidence of the occurrence of active inflammation in fourteen pulps from forty-one infected *clinically vital* teeth—37 per cent of the number.

These important results afford a substantial basis for the opinion, as expressed by the authors, that "the pulp is frequently invaded by microörganisms long before it has been exposed by caries or, indeed, in the absence of caries, by organisms which have passed into the pulp from the gingival region; and that such invading organisms give rise in the pulp to localized areas of inflammation which are not necessarily suppurative or gangrenous in nature, but rather granulomatous and progressive, leading to fibrosis or other changes. When suppuration and gangrene finally occur, it is in a tissue which has long been subjected to injury by milder types of infection, and suppuration is here merely the final stage of the process."—(W. J. G.)

Comment on McCormack's "plea for a standardized technique for oral radiography." By C. EDMUND KELLS, D.D.S., New Orleans, La..... 551

In a criticism of the paper recently published by McCormack (JOURNAL OF DENTAL RESEARCH, 1920, ii, p. 467), Kells writes that McCormack's technique has not been *standardized* in all respects, especially in the Coolidge-tube procedure and in the development of the films. Kells alludes to the fact that it was not explained *how* McCormack "*reproduced* sets of radiograms after intervals of three years." He is unable to understand "McCormack's disposition of the shadows of the malar bones." In his discussion of McCormack's statements of "conditions that may be recognized in, and correctly interpreted from, accurate radiograms," Kells directly denies the validity of some of McCormack's conclusions. He feels that "it is incumbent upon McCormack to explain . . . . *how* he can differentiate between a vital pulp and an empty canal;" and "*how* he tells that a filling is a deep one and not merely a veneer." See the next succeeding abstract.—(W. J. G.)

Reply to Kells' comment on McCormack's "plea for a standardized technique for oral radiography." By FRANKLIN W. MCCORMACK, Radiographer, San Francisco, Cal..... 557

Replying to the comment by Kells (preceding abstract), McCormack states that "no claim was made that the technique

described by me (him) is an exact or an absolute one; but the mechanical manipulation of equipment, tubes, and dark-room procedure, is so standardized, and the fixed rules operate with such slight deviations, that the work would become purely mechanical if it were not for the physical variations in patients." McCormack remarks that, "if the reproduction of radiograms after an interval of time is of sufficient interest to warrant the publication of a paper with half-tone reproductions of the radiograms, and photographic illustrations of the various procedures that must be used to explain the text," he will "gladly prepare such a paper." (McCormack and his collaborators have been invited to prepare it for publication in this JOURNAL.) McCormack explains, in greater detail, his method of preventing the occurrence of a radiographic shadow of the malar process over the apices of the upper molar teeth. Although admitting the force of some of the remainder of Kells' criticisms, McCormack defends his position on practically all the points at issue and suggests that "if Dr. Kells . . . . would differentiate between the terms *interpretation* and *diagnosis*, a great light might strike him." "Interpretation," says McCormack, "calls the attention of the diagnostician to the changes from normal that the radiograms show; and the radiogram, plus the radiographer's interpretation, give radiographic findings. *These findings must be checked clinically and verified before a diagnosis can be made.*"—(W. J. G.)

A medicated tooth-paste, with a full statement of its composition. By ALEXANDER LOWY, PH.D., Assistant Professor of Organic Chemistry, School of Chemistry, University of Pittsburgh, Pittsburgh, Pa..... 565

A brief statement regarding "F. E. I." tooth-paste, with an indication of its *complete* chemical composition. Dentists are invited to prepare this new tooth-paste and to try it for themselves, pending the publication by the author and his collaborators of the results of a clinical study of it now in progress.—(W. J. G.)

Progressive dentistry and stomatology. 3. The problem of devitalized (dead) teeth. By JOSEF NOVITZKY, D.D.S., San Francisco, Cal..... 567

A general statement of the danger of the development of systemic diseases from the retention of non-vital teeth.

Novitzky contends that every tooth with a non-vital pulp, or without a pulp, is a *dead* tooth—that such a tooth receives no nourishment, whatever. He states that examinations of hundreds of devitalized teeth have shown "that every one of such teeth, if left in the jaws, *was infected within six months of the time of devitalization.*" The author presents an illustrated description of his method for the thorough surgical removal of devitalized (dead) teeth and associated foci of infection, involving "removal of the corresponding buccal plate of bone," and appends a list of his related publications since 1914. Much of the author's research in this field was done in the Medical Department of the Leland Stanford, Jr., University under the guidance there of Dr. F. E. Blaisdell, Professor of Surgery. See the next succeeding abstract.—(W. J. G.)

Progressive dentistry and stomatology. 4. Comment on Novitzky's discussion of "the problem of devitalized (dead) teeth." By M. L. RHEIN, M.D., D.D.S., New York City..... 579

Rhein contends, in direct disagreement with Novitzky (preceding and succeeding abstracts), that "it can be sanely asserted that a large percentage of teeth with non-vital pulps can be so treated as to leave them free to function, without any danger of such teeth becoming factors in focal infection." Recalling Novitzky's statement that non-vital teeth are inevitably infected within six months of the time of devitalization, Rhein argues that, if Novitzky refers to bacteriologic examinations of such teeth *while the teeth were firmly held in the alveolar process*, Novitzky's "observations mean that none of the teeth was properly treated." Rhein believes that teeth with non-vital pulps, as treated by his own method, have not come within the scope of Novitzky's observation in this regard. Rhein states that "again and again bacteriologic tests of root canals ready for filling have given negative results. This statement applies also to canals where some reaming of the gutta-percha has been done months or years after the root filling had been inserted. Finally," he adds, "we can show roentgenographs of teeth covering a period of twenty years (and of some for a period of thirty years, where there were no initial pictures), in which we see the signs of perfect root fillings and of alveolar structures in apparently ideal physiologic condition in the periapical region. These facts entirely refute the views of Novitzky in this relation."

Rhein insists that a tooth "remains a vital organ so long as the cementum receives nourishment through the pericementum. Only if and after the pericementum ceases to function, can such a tooth be correctly called a *dead* tooth."

Rhein suggests that "the removal of the buccal plate of bone for the purpose of extracting a tooth through this orifice," as outlined by Novitzky, "has been recommended from time to time for many years." Rhein regards this procedure as doubtful in utility in all but "certain special cases." "It is questionable," he adds, "whether currettement of the average case requiring it cannot be done as effectively through the socket as by way of a buccal opening." See the succeeding abstract. —(W. J. G.)

Progressive dentistry and stomatology. 5. Reply to Rhein's comment on Novitzky's discussion of "the problem of devitalized (dead) teeth." By JOSEF NOVITZKY..... 585

The facts adduced by Rhein (preceding abstract), and which, in Rhein's belief, "entirely refute the views of Novitzky," are, according to Novitzky, *proof* of nothing in this relation. Novitzky adds: "(a) A negative bacteriologic test from a canal *ready for filling* means nothing. (b) Reamings of gutta-percha cannot afford evidence of the state of the tooth matrix, which is a far better culture medium than medicated gutta-percha. (c) Roentgenographs do *not* show the presence or absence of infection, nor do they always distinguish calcification from ossification. What many writers point to as a filling-in of bone is not a physiological condition but a *pathological* state. The deposition of blood salts and broken-down bone around the apex of a dead tooth should not be mistaken for newly formed bone." Novitzky states also: "My position is difficult because I cannot say that I have examined teeth treated by Rhein, or by any one of the 'hundreds of dentists' who have been instructed by him in his technic. I have, nevertheless, examined dead teeth that were most carefully and skilfully treated precisely according to the technic publicly advocated by him and have found all these teeth to be infected . . . . I have found nothing to convince me that Streptococcus viridans will not be found ensconced at the root ends of dead teeth 'hermetically' sealed by Rhein, just as they occur at the root ends of dead teeth treated by less clever operators than he."

In further direct allusion to Rhein's criticism, Novitzky remarks: "The statement that a 'tooth remains a vital organ, so long as the cementum receives nourishment through the pericementum,' is positively disproved by the fact that young cementum was deposited on a replanted tooth that had been boiled before replantation. A boiled tooth is certainly dead. It is not true that a pulpless tooth 'is retained in the alveolus *because* life continues in a portion of the pericementum.' The truth is, as has been pointed out frequently, that all dead teeth, including those that have been boiled, are retained because of the deposition of cementum on their roots."—(W. J. G.)

A success or failure in bridge-work: which? By CHARLES F. ASH, D.D.S., New York City..... 591

Ash states briefly the original dental condition of his patient, the nature of his diversified treatment, the character of the appliances provided, and the status of affairs at the termination of the treatment and at the end of the eighth year thereafter. The original conditions, the progress of the treatment, and the outcome are progressively illustrated in detail. The author does not answer the question he raises in the title, but those who discussed the paper (see page liii, section on proceedings) concluded that the treatment was a great success in practically all respects.—(W. J. G.)

The origin and evolution of the human dentition. (A palaeontological review.) **Part IV.—The dentition of the higher primates and their relationships with man.** By WILLIAM K. GREGORY, Ph.D., Associate Professor of Vertebrate Palaeontology, Columbia University; Associate in Palaeontology, American Museum of Natural History, New York City..... 607

This part of Gregory's exceptionally complete review continues directly the third part published on pages 357 to 465, inclusive, of the last previous issue. The scope of the review may be seen at a glance in the summary on page 607. The author's "summaries and conclusions for part IV," beginning on page 690, present an excellent abstract of the part of the review that appears in this number. (Part V, in conclusion of the review, will be published in the first issue of Volume III.)

In this part of the review, the author considers many of the facts of human dentition that relate particularly to the latest phases in the evolution of the teeth in man. The entire review

is a great fund of important facts and opinions in dental science, and must be *studied*, particularly in close comparison of the text with the many exceptional illustrations, to be fully appreciated.

(It gives us pleasure to announce that all the parts of this review will be issued together in book form after its publication in this JOURNAL; and that the author has generously arranged for the sale of this book *under conditions that will give the proceeds to the Endowment Fund of the* JOURNAL OF DENTAL RESEARCH.) —(W. J. G.)

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This statement presents the names of eighteen additional contributors to the Fund and reports an increase of $861.00 in the amount *paid* into it, two hundred and twelve subscribers having *paid* $4,821.15, which, with accrued interest ($211.98), makes the Fund a total of $5,033.13. Of this amount, $4,700 are held in U. S. securities at rates of interest ranging from 3.5 per cent to 6 per cent. *There have been no expenditures from the Fund.*

(It is hoped soon to enroll, if possible, *at least one thousand dentists as contributors to this fund*—as an assurance of widespread interest among dentists in the success of a journal devoted wholeheartedly and unselfishly to the advancement of dentistry—*before appealing to laymen for large sums to raise the fund to a total of several hundred thousand dollars. Contributions in any amount* are invited from all who may be interested in the permanent success of this JOURNAL.)—(W. J. G.)

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UNAVOIDABLE POSTPONEMENT IN THE PUBLICATION OF SEVERAL ADDITIONAL PAPERS

The growth of this volume, to a size about two hundred pages beyond our expectations, has made it necessary to postpone until March (1921) the publication of a number of additional papers now in our hands.

LIBRARY OF THE JOURNAL OF DENTAL RESEARCH

In order to facilitate the editorial and scientific work of this JOURNAL, a complete dental library will be needed. Contributions to such a library, which this JOURNAL is now endeavoring to assemble, of literary and historical matter in dentistry and stomatology, of any and all kinds and of any era (from clippings to books), are solicited from friends of this JOURNAL. Duplicates that may be received can be profitably used in suitable exchanges with other libraries. This library will be housed in the editorial office of the JOURNAL. Shipments may be addressed to this JOURNAL at 437 West 59th Street, New York City. Acknowledgments of gifts to this library will be made in successive numbers, and in a special summary in the last number of each volume. Publishers of dental journals and books are requested to favor this JOURNAL with copies of their publications, for the furtherance of dental research through the development of this permanent library.

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Dr. Wm. B. Dunning, 180 West 59th Street, New York City.
Dr. Henry W. Gillett, 140 West 57th Street, New York City.
Dr. F. C. Kemple, 576 Fifth Avenue, New York City.
Dr. Arthur H. Merritt, 59 West 46th Street, New York City.
Dr. Howard S. Seip, Allentown, Pa.
Dr. Martin C. Tracy, 46 West 51st Street, New York City.

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NEW BOOKS RECEIVED FOR THE LIBRARY OF THE JOURNAL OF DENTAL RESEARCH

THE JOURNAL OF DENTAL RESEARCH promptly acknowledges here the receipt of new publications presented to it. Books selected from those named on this list are reviewed below. Reviews are matter-of-fact statements of the nature and contents of the publications referred to and are *intended solely to guide possible purchasers*. The wishes or expectations of publishers and donors of volumes will be disregarded, if they should be incompatible with our convictions regarding the interests of our readers. The sizes of the *printed* pages, in inches, are indicated in each notice, after the numerals for the years of publication.

Transactions of the Sixth International Dental Congress (London, August, 1914). Compiled and edited by H. R. F. BROOKS. Published by the Committee of Organization, Hanover Square, London, Eng. (Received from the British Dental Association.) 1920; pp. 753; $8\frac{1}{2}$ x $5\frac{7}{8}$ (double column).

Block anesthesia and allied subjects; with special chapters on the maxillary sinus, the tonsils, and neuralgias of the nervus trigeminus. By ARTHUR E. SMITH, D.D.S., M.D., Oral Surgeon to Frances Willard Hospital and to House of Good Shepherd, Chicago. (With five hundred and ninety-five illustrations). 1920; 8 x 5; $15.00. C. V. Mosby Company, St. Louis, Mo.

A practical treatise on artificial crown-, bridge-, and porcelain-work. By GEORGE EVANS, D.D.S., F.A.A.D.S., New York State Board Dental Examiner; formerly Clinical Professor, College of Dental and Oral Surgery, New York; Lecturer, Baltimore College of Dental Surgery; Post-Graduates Lecturer, Royal College of Dentistry, Toronto, Canada. (*Eighth edition*, revised and enlarged, with 1,143 illustrations.) 1920; pp. 567; $7\frac{1}{4}$ x $4\frac{1}{2}$; $7.50. P. Blakiston's Son & Co., Philadelphia, Pa.

CREDIT TO PROSPECTIVE SUBSCRIBERS

Hygiene: dental and general. By CLAIRE ELSMERE TURNER, Assistant Professor of Biology and Public Health, Massachusetts Institute of Technology; Assistant Professor of Hygiene, Tufts College Medical and Dental Schools. *With chapters on dental hygiene and oral prophylaxis*, by William Rice, Dean, Tufts College Dental School, Boston. 1920; pp. 400; 6½ x 3⅞; $4.00. C. V. Mosby Company, St. Louis, Mo.

REVIEWS

See page (33), of the general matter for Vol. II, at the end of this number, for reviews.

EXTENSION OF CREDIT TO PROSPECTIVE SUBSCRIBERS IN FOREIGN COUNTRIES

Dental and medical journals are requested to announce that subscriptions for the JOURNAL OF DENTAL RESEARCH, including volume I, would be accepted from *dentists and physicians, and from scientific, educational and philanthropic institutions, in all foreign countries*, if presented (directly or through public subscription agencies) on formal assurances to this JOURNAL of the payment of the subscriptions, in each instance ($5.00), when the corresponding rates of exchange return approximately to normal.

SCIENTIFIC PROCEEDINGS OF DENTAL AND STOMATOLOGICAL SOCIETIES

FOURTH SECTION

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A LIST OF THE NAMES OF THE ORGANIZATIONS THAT HAVE VOTED TO MAKE THE JOURNAL OF DENTAL RESEARCH THE MEDIUM FOR THE OFFICIAL PUBLICATION OF THEIR SCIENTIFIC PROCEEDINGS

Association of the Allied Dental Societies, Inc.

American Academy of Dental Science

Massachusetts Dental Society

Harvard Odontological Society

Boston and Tufts Dental Alumni Association

First District Dental Society of the State of New York

Metropolitan District of the Massachusetts Dental Society

Harriet Newell Lowell Society for Dental Research, of the Harvard University Dental School

San Francisco Society for Dental Research

Colorado Society of Periodontists

American Academy of Periodontology

Columbia University Biochemical Association

In the case of the last named organization, only the dental and stomatological parts of its proceedings will be published in this Journal.

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PROCEEDINGS OF THE MASSACHUSETTS DENTAL SOCIETY

CHARLES E. PARKHURST, *Editor*

Fifty-six annual meeting, May 5, 1920. Sprague Hall, Boston Medical Library, Boston, Mass. President William J. Speers in the chair.

Scientific program. President's annual address, by William J. Speers, D.M.D. (this page). *Papers* by Percy R. Howe, A.B., D.D.S., Harvard University Dental School, Boston, Mass., on "*recent studies on nutrition in its relation to dental disease*" (to be published in the March, 1921, issue of the JOURNAL OF DENTAL RESEARCH), and by Clarence J. Grieves, D.D.S., Johns Hopkins Hospital, Baltimore, Md., on "*a classification of teeth, the pulps, apices, and attachments of which may be infective foci in local and systemic disease*" (published in the JOURNAL OF DENTAL RESEARCH, 1920, ii, p. 327).

PRESIDENT'S ANNUAL ADDRESS

WILLLIAM J. SPEERS

Fall River, Massachusetts

It now becomes my duty at this, the fifty-sixth annual meeting of our Society, to review with you our activities of the past year and to make suggestions for improvement.

Our meeting this year is confined to one day instead of being continued through three, which is our custom, for the reason that, as the National Dental Association will convene in Boston, in August, and other state societies have found by experience that it was practically impossible to obtain a good attendance at the "state meeting" when it was held near the date of the "national meeting," your Executive Committee decided to profit by the experience of others and to make this a one-day session.

When I took office one year ago I heard of expressions of dissatisfaction with certain conditions, with methods of doing things, and about how very little the society was actually accomplishing, etc. Now, most of us are

interested in our Society. We should be ambitious to see it accomplish great things. Many, I fear, are interested only in a passive way and, because of this fact, it is important to have a greater number of constructive spirits—men who will be ready and willing to do the duties assigned to them.

Most of us are busy men, our work is of such a nature that it demands most of our time; but, as has often been said, the busiest men are the ones who accomplish the most outside of the regular routine; and they are generally the ones to call upon when something important should be done. Some members appear to feel that the Society owes them something because they have paid a small sum into its treasury; instead, they should consider it a privilege to be associated with the best men in our state, some of whom have made a national reputation. To one of these we shall be privileged to listen today.

We are very fortunate in having a most capable and active Secretary, who has constructive ideas and is anxious to put them into action. But the Secretary and President cannot accomplish the greatest good without the coöperation and enthusiastic support of all the members. The man who takes no part in the active affairs of the Society is stealing a ride on the chariot of progress, and his standing as a member fails to measure up to that of those who achieve for the organization. A creed I would suggest for our guidance is this: "I will not criticise the Society for failure to accomplish results until I have paid my dues, attended the meetings, suggested to it the things I believe should be accomplished, and done all in my power to help to bring these things to pass."

The only ones who should expect to receive dividends from an enterprise are the ones who have invested something in it. Let us invest our thoughts, time, and energy, in our organization and we shall, I am sure, receive in return dividends of infinite value, not for ourselves alone, but such as will enable us to give more to others.

While making my visits during the year to our own district societies and to other societies outside of the state, I was especially impressed by the mental attainments and cordiality of the men I met. Again I felt exceedingly gratified that I had joined the ranks of this wonderful profession and, especially, that I am permitted to practise in this particular age when very great improvements are being made. This advance means greater responsibility on our part. I think we should constantly urge the adoption of higher educational standards. This can be accomplished in two ways: through the dental schools and through our dental literature.

During the past year we, as a profession, have had presented to us, a new dental journal, the JOURNAL OF DENTAL RESEARCH, which, in the judgment of many of our leaders in thought and action, is the very best yet produced for our profession, and stands as high in rank as the best journals of other professions. I need not say more relative to its attainments and merits, because all of you have received copies and are familiar with it; but I do wish to explain, briefly, the proposed future mode of distribution. It was my pleasure, with several other delegates from our Society, to attend a meeting in New York City, on April 17 last, in the interest of professional journalism. The JOURNAL OF DENTAL RESEARCH was the chief topic of discussion.

Some have asked, "What has become of the *Journal of the Allied Dental Societies?*" In answer I would explain that the editor, who had carried a heavy burden for a number of years, felt that he could do so no longer, with so many other demands on his time. In addition, the very great increase in the cost of publication made it imperative that some other plan be adopted. Just about this time the JOURNAL OF DENTAL RESEARCH came into existence and it was decided to continue the *Journal of the Allied Dental Societies* in the new journal.

The JOURNAL OF DENTAL RESEARCH has had a remarkable career, and is already nearly self-supporting. Consider what that means for a journal that does not accept advertising! This has been accomplished largely through the untiring efforts of its chief editor, Professor William J. Gies, a man of keen intellect, pleasing personality and, apparently, unlimited capacity for work.

Now, gentlemen, that we are fortunate in having this JOURNAL, let us show our appreciation by supporting it. The plan proposed is the following: For the past year we had the special opportunity to obtain the JOURNAL through our Society membership, for $1.00 a year per member, *in continuance of the old arrangement affecting the Journal of the Allied Dental Societies*, but the U. S. Government will not grant the second-class rate of postage to journals which sell any of their copies *at less than 50 per cent of their regular subscription rates*. Enjoyment of the second-class (reduced) rate of postage is essential to the success of the JOURNAL. Accordingly, the JOURNAL desires to obtain as many subscriptions from our membership as possible at the full rate, $5.00 a year. Here is where we are put on our honor, so to speak; for, if we do not wish to pay the full price, we may obtain the JOURNAL through the Society at *half-price*—$2.50 a year—the lowest the JOURNAL may legally offer. We have heard a great cry, for some time, for a strictly *professional* journal. *Now that we have a really admirable one, let*

us support it. I do hope that our Society will, in the very near future, present a large subscription list and show that the Massachusetts dentists appreciate a good thing.

Very briefly I wish to call your attention to another activity of the year. In March our Society received, from the Massachusetts Medical Society, an invitation to send two delegates, specifying that one be the chief executive, to attend, on the 18th, a meeting of a new organization called "The Massachusetts Central Health Council." Accordingly your President, accompanied by Dr. William Rice, attended the meeting.

The plans and purposes of this new organization were explained and are briefly as follows: (1) To bring about a better coördination of the public-health and social agencies of the state, ever striving to prevent an overlapping of the different activities, with a saving of time and energy. (2) To investigate, at the request of any constituent organization, any specifically designated health or social-welfare problems, and make recommendation in reference to same. (3) To keep advised, and to keep the constituent organizations advised, of proposed legislation of interest to any of these organizations. (4) To draft such proposed legislation as may seem necessary or advisable to promote the purposes for which the constituent organizations exist, and to take the measures that may seem advisable to secure the enactment of such legislation; and, also, to represent the constituent organizations at such hearings.

It seems to your President that this is another great step in the right direction, because it should make for greater efficiency in the solution of health and social problems of the state. Besides, it will bring the medical and dental, as well as other health organizations, in the state, into closer harmony with each other. Therefore, I hope our Society will take some action today whereby we shall assume our share of the responsibility and thereby justify the confidence of the medical fraternity.

We are hearing much at present about "mouth hygiene," a subject which cannot be over-emphasized. Here again our Society has been honored, and especially one of its members, by the appointment, on April 8, 1919, of Dr. Edwin N. Kent, to the position of Supervisor of Mouth Hygiene, associated with The Massachusetts State Department of Health. The activities of this office are many and most commendable, some of which are (a) registration of public dental infirmaries, numbering sixty-one at present, with others to be opened. (b) Standardization of these infirmaries. (c) A lecture service through "lecture sets," including manuscripts and lantern slides. (d) A series of letters on mouth hygiene, written to the school children of the state and read in each school-room by the

teacher. (e) A scheme for state-wide tooth-brush drills in our schools. (f) Pamphlets on "the importance of mouth cleanliness," and instruction for home care and other activities, which will be conducive of wonderful results.

Here again we are shown that dentistry is coming into its own.

In reference to illegal practitioners of dentistry, of whom I understand there are quite a number, I wish to say that the present laws are adequate and there are sufficient means of prosecution; but our State Board of Dental Examiners should be assisted in this matter by every registered practitioner, who should obtain evidence if possible, and inform the Board, of any cases which come to his attention. I am sure the name of the informer, in this public service, will always be held inviolate.

During the past year, a number of our members have returned to private practice after discontinuing their war activities. To all such I extend a cordial welcome back to our association and bid them again to take up their duties with us. I also humbly express to them, for you, our gratitude for what they have done for humanity and for the good name of our profession.

It has been my duty and privilege to attend a number of the meetings of our district societies during the year. I find most of them in a healthful condition. There is, however, an excellent opportunity to increase our membership by an active individual solicitation, because our membership at present is but 1,121 of a state registration of 2,850.

Our treasurer reports a sound financial condition, having been able in the past year to purchase an additional $800.00 worth of Government bonds, making a total of $4,000.00 so invested.

In August we shall have the privilege of entertaining the National Dental Association. Let us, as hosts, show that Boston is up and doing.

In closing I wish to express my appreciation of the honor shown me in my election to the presidency of this association and also to extend my sincere thanks to the other officers who have assisted me in the year's work.

PROCEEDINGS OF THE FIRST DISTRICT DENTAL SOCIETY OF THE STATE OF NEW YORK

WILLIAM B. DUNNING, *Editor*

Meeting held March 1, 1920. Academy of Medicine, New York City. President Frederick C. Kemple in the chair.

Scientific proceedings. Paper by Charles F. Ash, on "*a success or failure in bridge-work: which?*" (page 591). *Discussion* by Drs. L. M. Waugh, H. S. Vaughan, W. D. Tracy, P. R. Stillman, N. T. Shields, H. W. Gillett, A. Berger, J. H. Tuttle, and H. E. S. Chayes, of New York City; Dr. T. W. Maves, of Minneapolis, Minn.; and Dr. Ash (this page).

DISCUSSION OF DR. CHARLES F. ASH'S PAPER ON "A SUCCESS OR FAILURE IN BRIDGE-WORK: WHICH?" (PAGE 591)

BY DRS. L. M. WAUGH, H. S. VAUGHAN, W. D. TRACY, P. R. STILLMAN, N. T. SHIELDS, H. W. GILLETT, A. BERGER, J. H. TUTTLE, AND H. E. S. CHAYES, OF NEW YORK CITY; DR. T. W. MAVES, OF MINNEAPOLIS, MINN.; AND DR. ASH

Dr. L. M. Waugh (New York City): Late this afternoon I had the privilege of examining the casts of this case. I want to say, in defense of the apology that was made, that lantern slides always make casts look a great deal worse than they are. Very nice casts for orthodontic work, unless they are placed so that all the lines will appear parallel, seem to be out of place in focussing the slide. However, as Dr. Ash has apologized more or less for the condition of the casts, I am again given the opportunity, without offending the essayist, to say I believe we should make study casts for all parts of the mouth in which considerable areas are to be restored. I believe it is just as important for a man who is making bridgework as for the orthodontist, to make such casts—the careful orthodontist does not attempt to give an accurate opinion without them.

Some argue that they have had so much experience that it requires only a glance at the mouth to see what is needed; but the careful orthodontist thinks the lingual cusps are just as important as the buccal, and that the occlusion of those cusps should be studied. I believe in the importance of making study casts, and that they should be just as carefully done in the office of the general practitioner or specialist in crown and bridge-work, as the casts in the office of the careful orthodontist. I do not believe the dentist himself should take the time to trim the casts; but it is not difficult to find a trained young woman to trim casts just as carefully and nicely (sometimes rather more so) as the average dentist could do, because of his limited time for such work.

The importance of giving an honest opinion was emphasized by Dr. Ash. The patient went to a rhinologist, who suggested an operation to correct defective vision in the left eye. The patient rebelled, and consulted another rhinologist, who suggested that a dentist be consulted, but he was informed that a dentist had been consulted, and the mouth declared in good condition. Yet Dr. Ash tells us there were six sinuses discharging pus.

Complete examination of the mouth, as a routine procedure, is something dentistry is more in need of today than of almost any other thing. In a complete examination there are four kinds of tests that must be carefully considered, as follows:

(1) Clinical examination, with a record of the clinical history of general mouth conditions, and often general systemic conditions (especially in a patient sixty-one years of age), are at the basis of any dental diagnosis.

(2) Physical examination with the mouth mirrors, observation with the natural vision, and the judgment gained by the trained eye regarding the color and texture of the oral tissues, will always remain a part of the basis of dental diagnosis. However, these must be reinforced by a complete set of good radiographs—there should be not only one of a suspected region, but at least three, sometimes five or six, sometimes ten or eleven. A single radiograph is not sufficient. Do not think an extremist is talking—I believe I am justified in saying this from my experience with radiographs in orthodontia. Even though a single radiograph may confirm clinical appearances, several radiographs should be made, to confirm our diagnosis, before one condemns a given region, or considers it healthy. One cannot make a definite diagnosis, or give a definite opinion, from only one radiograph. I am satisfied that three from different angles are better than a set of stereoscopic ones.

(3) Thorough tests with the faradic or galvanic current—the vitality tests. I feel, however, that a vital pulp is not necessarily a healthy pulp, any more than an individual who can walk along Fifth Avenue is necessarily a healthy man or woman. We know that many individuals have hearts which are so bad that something unusual may cause complete cardiac failure. We know there are functioning kidneys that are diseased. The finding that a dental pulp responds to the vitality tests does not always mean that it is healthy—in fact, a diseased dental pulp is often more responsive to the vitality tests than a normal pulp.

(4) The use of casts, in making a diagnosis, *where considerable restoration is to be made.*

I do not believe anyone has a moral right to give an opinion before he has made those four tests.

With a great deal of abhorrence we listened to the recital, by Dr. Ash, of the case of the patient who would not remove his bridge. How unclean and terrible we think that is, for a patient not to remove his bridge! But why should we be surprised? Do you think that that bridge, made in the masterly manner in which it was constructed, is less clean than any of the fixed bridges we insert? I have made many, and I am sorry for 99 per cent of them. Did you ever see a really clean one after it had been worn for only a week? Small orthodontic appliances in the mouth will not remain clean even for three or four days—there are tiny recesses for decomposing food and little places where microorganisms will assemble. We have made bridges and have told patients to clean the surfaces under them with little swabs of cotton—even those made by Dr. Young—and yet I should not say that any one of them was kept clean. Food and debris inevitably collect and putrefy under them.

Success versus failure. Not being able to discuss the paper, I shall discuss its title—"a success or failure in bridge-work: which?" I presume Dr. Ash wanted the audience to decide whether his efforts had been a success or a failure. The farther I go in dentistry,

the more I feel we must realize that our work is only temporary. Physiologically we grow older, and tissues grow more fibrous, and cells are not so active. In our dental efforts, it is a struggle to keep the work in the mouths of our patients continuously useful to them.

In Dr. Ash's case, the individual was served well for eight years. At the beginning he had infection and impaired vision. He was threatened with an operation to which he objected. The service which Dr. Ash rendered, even though he thinks one tooth should have been extracted, has given that man dental and perhaps physical comfort far beyond what he would have realized, even though the operation upon the nose had been performed. Now we find it is not quite perfect from the standpoint of occlusion on the upper right side. We find the overhang of the buccal cusps is not quite so marked, although it did not show so well on the lantern slides—the casts show they do not overhang quite so much. There is a greater tendency for the individual to bite the cheeks in such cases. On the left side the mesial incline of the lower molars, by striking against the uppers might, in time, be the cause of a pathological condition, for every time the mouth is closed, those lower teeth tend to be forced backward. But was this case a failure? I should say it was decidedly a success, even if it ceased its usefulness now. I think any case that gives eight years of comfort to the patient is a success—a decided success, even though it may not be a perfect success. It was with that feeling that I listened to Dr. Ash's presentation of what to me was a very interesting case, and a most successful one, done in a thoroughly workmanlike manner—a case of which I should be proud to have been the maker.

Dr. H. S. Vaughan (New York City): I have listened with great pleasure to Dr. Ash's presentation of his subject. It differs from those to which we are accustomed, in the fact that we usually have a discussion of methods and processes. Here we have an unusual case, showing the clinical history of ill-health, and full data on the conditions that existed prior to Dr. Ash's work. We followed the case progressively by radiography to its termination.

I shall discuss more particularly the infective conditions as they were explained to us, some of which are rather extreme. You noticed, in the radiographs, the great amount of destruction over the incisor and cuspid teeth that were involved. Four or five root-resections were performed, followed by curettement and removal of the infected tissue. Hindsight is always more positive than foresight, but Dr. Ash has shown rare skill and judgment in the way he has carried this case through.

Dr. Grieves indicated, in the statistics in his paper last month,[1] that only about 50 per cent of the teeth that have been devitalized (and filled under favorable conditions) remained free from apical infection. Here, in the hands of this skilled operator, we have a 100-per cent success in the root therapy, though we are now reaching the point where we feel that teeth should not be devitalized if it can be avoided. The left lateral incisor, that serves as the anterior abutment of the removable bridge, shows some thickening of the pericementum. This, I believe, is due to trauma rather than to apical infection, because the thickening extends not only around the apical zone, but around the sides of the root as well.

I shall not discuss the matter of fixed or removable bridgework, but am struck by the healthy appearance of the bone around the abutment teeth of the fixed bridges, as well as of the intervening bone, showing that no pathological process has been going on.

In the case of the lower left molar: eight years ago we were more inclined to sanction root-canal filling and ionization; but I believe this case is added proof against attempts to

[1] Grieves: JOURNAL OF DENTAL RESEARCH, 1920, ii, p. 339.

clear up a chronic extensive infection by root therapy alone. You have organized infected tissue surrounding a root apex that has lost its pericementum; the lacunae and canaliculi are thickly permeated by active bacteria, and are therefore beyond the reach of the most thorough root-canal therapy. When such teeth are to be retained, root-canal therapy must be supplemented by surgery of the root apex and surrounding tissues.

The small piece of foreign material over the cuspid can readily be removed. Its presence is due to an error in technique, but does not disprove the value of the procedure.

Dr. Ash has asked the question: "Success or failure: which?" Considering the patient's age, his general condition, his broken-down health, on one side; and the restored occlusion, renewed health and vigor, on the other side; I think it a most decided success. The lower left molar should have been removed, but weighing that error in judgment against the general result attained, we should class it as a most successful result.

The society is to be congratulated upon receiving such a presentation. We shall learn a very great deal from men who have the courage to show cases of which the treatment may be debatable. I hope many more will follow Dr. Ash's example.

Dr. W. D. Tracy (New York City): Dr. Ash told us about the clinical symptoms, and spoke of the infective side, and the nasal disturbances; but, in closing, he said nothing about the improved condition of the patient, leaving that for our inference, and we naturally inferred that the patient became cured of those troubles.

Dr. Ash: The distorted vision and the disturbance in the nasal passages cleared up without intervention by the rhinologist, or the oculist, after the dental infections were removed. The patient has been in unusually good health since.

Dr. P. R. Stillman (New York City): A lecturer upon the subject of anatomy said that it took more physical energy to smile than to grieve, for the reason that a smile brought into action twelve sets of muscles while the misanthrope used only six. In my opinion, it required a greater and finer moral courage on the part of Dr. Ash to show us a case whose success is debatable, than to have kept this case, together with its valuable lessons, in the seclusion of his professional records.

While it is possible to criticize certain details in the case here presented, it is my belief that, taken as a whole, it should be considered a success. This is particularly true when we consider the status of knowledge of the various branches of dental science at the time this case was undertaken. For after all, we should, in large part, base our estimate of the worth of a man's service on the professional knowledge he was able to command during the period it was rendered. It is not to be understood, of course, that we should permit the continuance of conditions which might be detrimental to a patient's health. But, when an invalid receives such treatment as we have been shown, and, eight years afterward, presents a picture of robust health, we can only praise the treatment that has contributed to this result.

Dr. Ash lays his professional reputation open to attack when he exhibits this particular case. For this I commend him. There are few among us who could have done as well; particularly eight years ago.

It was my pleasure to be intimately associated with Dr. Ash in the treatment of this case. I recall, clearly, the condition of the patient's health, which bordered on invalidism. And I am more than pleased to be informed of the present good health of this very charming gentleman.

Those who have made bacteriological examinations of devitalized teeth, after extraction, have found a high percentage of infection, even when the radiographic evidence seemed to indicate a condition of local sterility. We must assume, therefore, the probability of the existence of infection around the apices of a large majority of all devitalized teeth. While of great importance, this condition is subordinate to the adequacy of the body defences against infection. Bacteria are ever present in the environment of the human organism and are constantly gaining access to various parts of the body. But these organisms have little direct significance until they produce disease. The important element in the situation, then, is not simply the invasion by bacteria, but the fact that the body defences against that invasion have proven inadequate. In the case under discussion we should not assume that these periapical regions are free from pathogenic bacteria, but that the immunity of this individual is at present sufficient for his needs.

The restoration of the function of mastication, which in this case had been seriously diminished, has undoubtedly contributed largely to the happy result.

From the standpoint of the periodontist, I take pleasure in testifying that the occlusion was harmonious; that the margins of the crown bands were correctly fitted; that no recesses or catch-alls were created; in a word, that all the requirements of the periodontist, from the standpoint of restoration, were amply satisfied.

Dr. Ash requests a vote as to the success or failure of this case. I cast my vote in the affirmative.

Dr. T. W. Maves (Minneapolis, Minn.): I am very much pleased to receive an invitation to speak in the discussion of this paper. I shall say only a word of highest praise for Dr. Ash. Out our way there is one outstanding issue in dentistry, although it was not the main issue eight years ago. The issue, now, is the question of focal infection from non-vital teeth—I have not a word to say after seeing this case. The radiographs show conclusively that Dr. Ash has accomplished his mission with this patient.

Dr. N. T. Shields (New York City): This paper appeals strongly to me, because it describes something I have been striving for many years to do. I wish to offer a little criticism—just what Dr. Ash asked us to do. I think he said there were six running fistulae. I wonder whether those teeth were properly filled. Many of us have had patients with such fistulae, which have healed; and the patients have died with those regions still healthy —and healthy without the necessity of amputating the roots! Dr. Ash said good-humoredly that a root end was encapsulated. There were several cases where the gutta percha penetrated the roots, sometimes extending a quarter of an inch beyond the apices. That made no difference, because he was going to amputate them. If the fistulous teeth had been carefully filled for a different purpose—if they had been filled beautifully to the apex, not beyond it, with a solid material incapable of absorbing moisture, such as non-cohesive gold, and with oxychloride of zinc, which passes into the microscopic tubules—would not the fistulae have healed and remained so? The teeth were extracted, and the case was restored in a beautiful way; and incidentally the entire upper denture was made one denture. That has been my plea for a number of years, in cases where it was necessary for the restoration of the teeth, to have the appliance rest uniformly on all the teeth—not to have the individual motion that you hear so much about in this society.

Dr. Waugh asked if any mouth could be found to be clean, after a fixed bridge was in it for one week. I wish to say that when a fixed bridge is put into the mouth properly, and the gold properly polished, the uncleanliness there is infinitely less noticeable than

that on the teeth which have not been bridged. What is the condition of the mouth of the very patient to whom he referred? After the gums begin to recede a little, it is almost impossible for the patient to keep the teeth clean; but if the parts are restored on scientific principles, it is almost impossible for the patient to keep them unclean.

Dr. H. W. Gillett (New York City): It occurs to me that, in the wording of the title of his paper, Dr. Ash had less in mind a verdict as to the success or failure of the individual case he presented, than the success or failure of a principle in bridge-work. Before I discuss the paper, I want to refer to the question regarding the dividing line between the meanings of "partial denture" and "bridge." In my vocabulary, everything is a bridge that uses natural teeth as supports to take the thrust in mastication. I do not mean supports in the sense of arrangements to prevent such appliances from dropping out of place. In every case, however, where a lug or a rest or anything of that type—whether fixed or removable—is used to support an appliance against the thrust of mastication, I should consider that the principle of the abutment is involved and, consequently, that the appliance is a bridge.

I shall not speak in detail about Dr. Ash's interesting and valuable paper, but concerning its relation to a previous paper and to the discussion of that paper.

A few months ago, we listened to the reading of a paper by Dr. Tinker—an advocacy of the 100-per cent-vitality idea, supported by some pictures of fixed bridges. We have seen tonight two or three (at least two) different types of appliances that exemplify the same principle of fixation of teeth to each other; also some beautiful examples of removable bridge-work. I have been in practice long enough to have passed through most of the stages of opinion and practice represented in these papers and discussions. I can go back a number of years and say, concerning many of the types of bridge-work shown: "Yes, that is exactly what I believed then." I have gone, in this way, from the rigid fixed bridge; the bridge fixed at one end, and resting on something at the other end; a rigid bar extending between teeth; bridges retained by fixtures extending out over the gums; and so on, to the several types of removable bridges.

Dr. Ash has shown us pictures, and given us the history, of cases of different types that have been successful, in that they have served the patient satisfactorily for a period of years, and the radiographs show a satisfactory condition. Dr. Tinker showed us similar pictures of fixed bridge-work. I do not apply fixed bridges at present. Occasionally, however, cases of fixed bridges made ten to twenty years ago come to my office, and I find that the bridges are still doing good service, and that they appear to be in good condition, at least so far as any such appliance can be expected to be, after fifteen or twenty years of active service.

I want especially to call your attention to one condition that is present in all the successful cases shown here. In every case of fixed bridge-work of my own, that I consider a success, the same principle is inherent. Every one of them has been so constructed, and the mouth conditions of the individual have been such, that it is *possible for the patient to keep the appliance clean.* There are mouths and conditions where small fixed appliances can be kept as clean, as Dr. Shields suggested, as the natural teeth themselves.

It may be that the dental millenium will sometime arrive, when one type of bridge-work will obtain for every case that presents; but it is evident from what was shown tonight, that there are several ways of gaining success. Frankly, I feel that the millenium has not yet arrived, when one type of work will answer for every type of case.

I want to say something that I wish I had stated when Dr. Tinker was here. He showed pictures, on the screen, of cases that I do not believe any individual can keep clean. I do not believe that an uncleanable bridge will be successful for any length of time. The fact that it has vital teeth under it will not save it, if its surroundings are unclean. Dr. Ash has shown us one case where, although it is possible for the patient to remove the bridge and maintain cleanliness, the patient fails to do so; but that is not Dr. Ash's fault. It is not the fault of the operator if the patient ignores instructions.

Recall the pictures shown tonight, and then, in comparison, recall Dr. Tinker's pictures. I ask those of you who have run the whole gamut of fixed bridges and removable bridges to think over this matter of cleanliness and its importance. I believe most of you will agree that you can remember cases of several types that have done good service, and have not shown disastrous results about the teeth; that you have seen successful cases, occasionally, of all the different types of *fixed* bridge-work, but that, in the majority of mouths, they were unsuccessful. The successful cases seem to have been—and I believe you will agree with me—those in which the patient kept the abutments and adjacent areas clean. I believe that *cleanliness is the keynote to successful bridge-work.*

Dr. A. Berger (New York City): I realize how incompetent I am to discuss, from a prosthodontist's standpoint, the case presented by Dr. Ash. However, I know enough about prosthodontia to say that this is a wonderfully constructed case, and one which would defy criticism from a prosthodontist's standpoint. I shall take the liberty, therefore, to discuss it from a pathological point of view.

At this time the dental profession is being buffeted from all sides by a good deal of empiricism. Last month Dr. Grieves read a paper, before this Society,[1] in which he told us that cases of dental infection, such as Dr. Ash showed us, are to be condemned. I am not prepared to state whether Dr. Grieves is right or wrong, but he attempted to show that those cases in which the lamina dura undergoes destruction, and which he places in "Class IV," should not be left in the jaw.

Dr. Ash brings before us such a case, which presents a number of these conditions. The gentlemen who preceded me in this discussion avowedly state that the treatment was a success. On what basis has this success or non-success been determined? I think Dr. Ash is liberal enough to admit that there are many conditions in the case, which, from a radiographic standpoint, are open to serious criticism in the light of dental pathology As is indicated by the title of the paper, there is some doubt in Dr. Ash's mind about the absolute success of the case. He knows and all of us concede, that so far as mechanical utility, and beauty and harmony in construction and adaptation are concerned, this work could be equalled by few. However, the real point in question is: does the excellence of the prosthetic work justify continuance of the pathological state of the abutments?

This is an occasion for retrospection, but let us not make it one for retrogression. Dr. Ash is looking backward. The case is most instructive. We can take Dr. Ash's word for the statement (at least it convinces me) that the patient's condition has become greatly improved. This may mean only that the patient was so overburdened by the infection originally that his resistance could not withstand it, and that *some* of the burden has been taken off by Dr. Ash. Nevertheless, the patient may still be carrying a load that the oral conditions impose upon him but which he should not be allowed to carry.

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[1] Grieves: JOURNAL OF DENTAL RESEARCH, 1920, ii, p. 327.

Knowing that he keeps abreast of everything new in dentistry, I most respectfully ask Dr. Ash whether, with the understanding he has of the systemic complications of his patient and with his present knowledge of dental pathology, he would treat today the same case in the same way.

Dr. J. H. Tuttle (New York City): This case has been a revelation to me, and has proven to me many things in regard to prosthodontia and to different methods of restoration of lost teeth. I think Dr. Ash had quite a deep lesson in mind when he brought this case before us—that there may be more than one way of solving a problem. He has fixed bridge-work and removable bridge-work demonstrated in the same case, and he has abutments over vital teeth and over non-vital teeth—all of which have been a success from the point of view of comfort and improvement in the patient's health. We are prone, as Dr. Gillett just stated, to take up each new thing as it comes along, and to think it is the only way of solving our problems. Dr. Ash has shown us that there is more than one way, if we use good judgment in selecting the particular mode of procedure.

In the solution of this case, Dr. Ash selected more than one method of procedure. The patient was sick when he came to Dr. Ash. He was suffering from a lesion in the nose and from a pathological ocular condition, and he recovered after the dental operations were completed. I do not see how we could call this anything else than a success. If we can succeed in arriving at such results by well known and tried methods, let us use them rather than jump at all the new things that come along.

Dr. H. E. S. Chayes (New York City): Dr. Ash ought to be satisfied. He presented his multiplicity of methods. If we are to take his presentation as evidence of the patient's satisfaction (and the patient is satisfied), then why should we not be satisfied? The First District Dental Society, and the dental profession of the United States of America, ought to send a delegation to the Almighty, and tell Him what a foolish thing it is to use only one method of putting teeth in the human mouth, when a multiplicity of ways can be used! Why should we not go in the way that nature points out to us? Nature took two million years—if our statistics tell us correctly—to evolve the human race.

None of the radiographs exhibited tonight shows freedom from disease in the bone areas. None of them shows any remarkable enhancement in health; although in all, we will agree, Dr. Ash's good judgment was shown—a man at sixty years presented himself with these lesions, Dr. Ash did the best he could under the circumstances, and the man is still alive to tell the tale! His operation would have been less successful, if, instead of the healing of those fistulae, the patient had died. Let us not delude ourselves. The inhibition placed upon the mouth with that type of bridge proves to me that my friend, Charles F. Ash, is a first rate embalmer! I do not say this in any attempt to disparage the work he did. I say that, for a patient sixty years of age, with no possibility of great change in those tissues, which are more or less fixed in their habitat, Dr. Ash did very well. For a patient of thirty-five years, that course would have been an insane procedure; but in this case, Dr. Ash showed good judgment, and the patient was kind enough to live long enough to tell us what a good thing it was. In perhaps seven cases out of ten, the treatment would not have been so successful. I congratulate Dr. Ash. I am glad also that he gave Dr. Shields a chance to warm the cockles of his heart.

Personally, I have no desire to bring forward either my successes or my failures, but I want to say as earnestly as I can, that there is nothing so futile as the use of a multiplicity of methods, when you minister to public health. There is but one thing that

should guide you. Say to yourself: "What did nature do, before I came upon the scene, to maintain the functions of that particular organ?" We must do our work in such a way as to simulate as nearly as possible, the actions, motions, and conditions we find in the oral cavity, as expressed by each tooth in its socket, placed there by the Greatest Hand, and with a greater skill than any one of us is capable of exercising.

A Member: Did the focal infections of the patient produce systemic effects; and if so, what was done in regard to the resulting systemic disturbances? Were cardiac disturbances among them?

Dr. Ash (in conclusion): I have just been asked whether, in my opinion, the oral condition of the patient caused systemic disturbances and whether the work I did cleared up those infections. Yes, there were such disturbances and the infections did clear up. There were no cardiac disturbances.

I did not present this paper in the expectation that it would have your entire approval. There were some things for which I could have been criticised more than I have been. Perhaps I can see the deficiencies more clearly than you can—I could hardly expect that, in a rapid survey, all the points of interest would be singled out. I wish some things about this case were different.

We assumed, after careful examination had been made of this patient by specialists, that the conditions were caused by infection. Infections were not discoverable anywhere else in the patient's system, but they were very definitely located in the mouth. An effort was made to remove the infections. The four teeth that were immediately extracted were hopeless. The roots were very much involved in pus areas, and, in my opinion, nothing but extraction and curettement could clear up those areas.

To Dr. Berger's question—whether, in the light of our present knowledge of infections, I would proceed in the same way—I answer very definitely, I would not. I hope I have sufficient intelligence to be able to distinguish, by observation, conditions that are not entirely successful, and to use what knowledge I can get to try to better such conditions. For instance, in the mechanical restoration of this case, I believe the occlusal plane of the molars on the left side is not properly adjusted, and that it could have been corrected. The correction would have required the devitalization of the third molar, however; my procedure was intended to avoid this necessity.

I think I made a mistake in permitting the left lower second molar to remain in place. It should have been extracted when I discovered that I could not reach the apices of the roots, and that there was a rarefied region there. I am not entirely sure that the sodium-potassium treatment was not responsible for that condition. I do not believe increased rarefaction could have occurred otherwise, in two or three days, to the extent it did in this case.

I did not present this case with an idea of taking a vote, nor with an idea of raising the question whether this particular case was a success or a failure; but rather to suggest the inquiry whether we are getting successes and failures generally.

The suggestion, that there was no regeneration of bone under the bridges on the site of the extracted teeth, was not well founded, it seems to me—I believe there was regeneration of good healthy bone in those places. Of course, one swallow does not make a summer; but when one can present cases of fixed bridge-work in a mouth after eight years, and show there has been no resorption of bone around the abutments or under the saddles, it is proved conclusively, it seems to me, that there are places where fixed bridge-work can be used successfully.

Dr. Chayes suggests that we send a committee to the Almighty, and ask why He should not use a multiplicity of ways of putting teeth in the human mouth. But He *does*—there *is* a multiplicity of ways. I am sure you will all agree with me that the teeth are not placed in only one way in human mouths.

I believe the *decisive* factor in determining whether we should use a fixed or a removable bridge, in a given case, is the presence or absence of a tendency to pyorrhea. The greater the tendency to pyorrhea, the more the insertion of fixed bridges should be avoided. I base this conclusion on the following facts: We know that the greater the degree of pyorrhea in a given case, the greater the necessity for perfect cleanliness in order to prevent progressive loss of teeth from pyorrhea. It is easier to keep an abutment clean when the bridge can be taken off. Consequently, in order to make the greatest degree of cleanliness attainable in pyorrhea, a removable bridge is, in general, preferable.

I was very glad to hear what Dr. Gillett said about insisting upon having patients keep their teeth clean.

Dr. Shields asked whether an infection could not be cleared up if a properly placed gold filling were put in the canal and the balance filled with oxychloride of zinc. I should like to see a condition of that kind clear up under such a treatment. My own opinion is that it would not occur. I believe that, where there is infected bone around the apex of an infected tooth, such bone would not heal after that kind of treatment. I do not believe regeneration of bone would occur under such conditions.

In view of the clinical facts—this patient not having been in perfect health at the outset—I should like to ask those who are so insistent upon the removal of all non-vital teeth, whether, in this case, they would have approved (or insisted upon) the extraction of all the upper teeth, because there was only one vital tooth in the upper jaw. Would that patient have been better served with a full upper plate than with what he has? I doubt it. I believe the patient has had more comfort with his present apparatus; and, inasmuch as he has retained good health, I think he has been well served.

It may be contended, of course, that if the general health of the patient ordinarily is not good, we "take chances" in such cases. I think I may be censured for having left some of the teeth in the mouth without proper filling of the roots to the apices. In the light of what I have learned since the teeth were treated, I would not now leave them in this condition. However, I believe that the only infection that may *possibly* exist in this mouth at present occurs about the small foreign body over the right upper cuspid or at the apex of the left lower molar or both.

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